Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

**CSAS** | **SCCS**

**Canadian Science Advisory Secretariat** | **Secrétariat canadien de consultation scientifique**

**Research Document 2002/044** | **Document de recherche 2002/044**

Not to be cited without permission of the authors * | Ne pas citer sans autorisation des auteurs *

# Herring acoustic surveys for 2001 in NAFO Divisions 4VWX

# Relevés acoustiques du hareng de 2001 dans les divisions 4VWX de l'OPANO

G.D. Melvin[1], L. M.Annis[2], M.J. Power[1], F.J. Fife[1], K.J. Clark[1], and R.L. Stephenson[1].

[1]Marine Fish Division
Department of Fisheries and Oceans
Biological Station
531 Brandy Cove Road
St. Andrews, N.B.
Canada E5B 2L9

[2]Herring Science Council
35 Hawthorne St
Yarmouth, Nova Scotia, B5A 4B4

* This series documents the scientific basis for the evaluation of fisheries resources in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

* La présente série documente les bases scientifiques des évaluations des ressources halieutiques du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Research documents are produced in the official language in which they are provided to the Secretariat.

Les documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au Secrétariat.

This document is available on the Internet at: Ce document est disponible sur l'Internet à:
http://www.dfo-mpo.gc.ca/csas/

ISSN 1480-4883
© Her Majesty the Queen in Right of Canada, 2002
© Sa majesté la Reine, Chef du Canada, 2002
Canada

103-01234/

**Abstract**

The distribution and abundance of Atlantic herring in NAFO Division 4VWX was documented from survey data collected primarily by commercial fishing vessels during structured, mapping and research surveys. Surveys were conducted on the main spawning components in accordance with a pre-season plan. The spawning stock biomass for each component was estimated by summing the results of surveys undertaken over the spawning season at scheduled intervals (i.e., >10 day). In 2001, 3 surveys were conducted in Scots Bay, 3 on Trinity Ledge and 6 on German Bank following established protocol and providing coverage of the spawning areas consistent with previous years. As a result, the estimated biomass was considered representative of the spawning components. Biomass estimates for Scots Bay, Trinity Ledge and German Bank were approximately 164,000t, 14,800t, and 191,000t for a total SSB of 370,000t in the traditional survey areas. Another 88,000t of spawning fish were observed near Spectacle Buoy, 3,000t around Seal Island and 46,000t on Browns Bank giving a total of 507,000t for the 2001 spawning season. The significant and continued decline in biomass since 1999 on German Bank is cause for concern. Biomass estimates for surveys of the coastal Nova Scotia spawning components and the offshore Scotian Shelf spring/summer feeding aggregations are also presented.

**Résumé**

On documente la distribution et l'abondance du hareng dans les divisions 4VWX de l'OPANO d'après des données de relevé recueillies principalement par des bateaux de pêche commerciale lors de relevés structurés, de relevés de recherche et de relevés par contours. Les relevés visaient les principales composantes de reproducteurs conformément à un plan établi avant la saison de pêche. On a estimé la biomasse du stock reproducteur (BSR) pour chaque composante en additionnant les résultats des relevés effectués durant l'époque de la fraie à des intervalles préétablis (c.-à-d., > 10 jours). En 2001, trois relevés ont été effectués dans la baie Scots, trois sur la chaussée Trinity et six sur le banc German suivant le protocole établi et visant à assurer la même couverture des frayères que par les années précédentes, ce qui a permis de considérer la biomasse estimative comme représentative des composantes de reproducteurs. Les estimations de la biomasse pour la baie Scots, la chaussée Trinity et le banc German se situent à environ 164 000 t, 14 800 t et 191 000 t, ce qui donne une BSR totale de 370 000 t dans les zones de relevé standard. On a aussi trouvé 88 000 t de reproducteurs près de la bouée Spectacle 3 000 t alentour de l'île Seal et 46 000 t sur le banc Browns, pour un total de 507 000 t pour l'époque de la fraie de 2001. Le déclin important et continu de la biomasse depuis 1999 sur le banc German est préoccupant. On présente aussi des estimations issues de relevés de la biomasse des composantes de reproducteurs fréquentant les eaux côtières de la Nouvelle-Écosse et du hareng s'alimentant dans les eaux hauturières de la plate-forme Scotian au printemps et en été.

## Introduction

For the 2000/2001 fishing season, industry based acoustic surveys again formed an important part of the evaluation of 4WX herring stock status. Data obtained from automated acoustic logging systems aboard commercial fishing vessels during structured surveys have been incorporated into the assessment process since 1998 (Melvin *et al.* 1998, Stephenson *et al.* 1997). Prior to the development and implementation of the automatic acoustic systems, biomass estimates were qualitative and relied on the experience of the observer to estimate the amount of fish from mapping surveys (Melvin *et. al.*, 2002).

The practice of using commercial fishing vessels to evaluate spawning stock biomass (SSB) was initially implemented to provide additional protection of individual spawning components within a global TAC during a period (1994-95) of declining biomass. The original qualitative approach, commonly referred to as the "survey, assess, then fish" protocol, continues today, but uses a quantitative acoustic methodology with a standard survey design (Melvin and Power, 1999; Melvin *et al*, 2001, Power *et al.*, 2001). The herring industry has also recognized the value and contribution the surveys make in evaluation of stock status. As such, they have entered into Joint Project Agreements (JPA) which define the level of effort and support to be provided by DFO and the fishing industry.

Over the past 5 years the 4VWX herring fleet has undertaken numerous surveys of major and minor spawning grounds and provided direct input of their quantitative observations into the assessment process (Figure 1). Since 1999 improvements have also been made in the areas of survey design and in the standardization of survey coverage to a point where they can be considered comparable from year to year (Melvin and Power, 1999; Melvin *et. al.*, 2001, Power *et al.*, 2002).

The purpose of this document is to report and summarize the 4VWX stock assessment related survey data collected during the 2001 fishing and survey season.

## Methods

Acoustic and mapping surveys using commercial fishing vessels have been employed to estimate the spawning stock biomass of individual components within the stock complex for the past 5 years. The methods and procedures are well established and documented in previous research documents (Melvin et al., 2001). This section provides only a general overview, a description of new methods and changes in approach. The detailed description of the methodology and analytical approach is presented in Appendix A.

Data collected and used to estimate the spawning stock biomass during the 2001 fishing season were collected during both standard fishing operations and

structured (i.e. organized) surveys. Structured surveys were either acoustic or mapping surveys (Melvin *et. al.*, 2001). In 2001 no major changes from previous years were made to the protocol established for either acoustic or mapping surveys. The 12 surveys scheduled for 2001 were completed on or near the tentative dates scheduled. Table 1 summarizes the number of structured surveys undertaken for each area. Additional acoustic surveys were undertaken on German Bank, Seal Island, Browns Bank, Port Mouton and Eastern passage during the 2001 spawning season and off Chebucto Head (non-spawning aggregation) in January of 2002.

In general, surveys were conducted in accordance with the protocol established in Melvin and Power (1999). Furthermore, there was an improvement in the survey design in situations when only a single aggregation of fish was surveyed. In most cases, vessel captains established a series of parallel transects to document the fish, rather than the unorganized search pattern common in fishing operations. The trend of moving away from mapping surveys toward standardized and scheduled acoustic surveys continued. The majority of information on the 2001 fishing season presented in this report originated from structured acoustic surveys in which data from the acoustic logging systems and non-logging vessel observations were combined to determine the survey area and biomass estimate. However, there were several surveys that did not follow the established protocol nor cover the defined area of the spawning ground. The only significant change that occurred in 2001 was in the estimation of the length-weight relationship.

Length/Weight Relationship

In previous years the weight in the target strength (TS) equation (Appendix A) was estimated using a length/weight relationship developed from monthly data. In other words, length and weight data from all areas for a given month were used to calculate a length/weight relationship. This relationship was then used to estimate the weight of a fish for a given length. In 2001 this was changed slightly to improve the estimate of weight. Given the extensive nature of our sampling it was possible to obtain a significant number of detailed samples (length/weight data) within a 10 - day window (5 days either side) about each of the surveys. This resulted in a small decrease in the estimated TS (-35.5) of a standard 28cm herring (Table 2), for all surveys dates except Scots Bay on July 31.

Acoustic Systems

Eight automated acoustic logging systems were deployment on commercial fishing vessels: five systems connected to the hull mounted transducers of purse seiners, two to boats in the gillnet fleet and a portable system for multi-vessel deployment. Systems were installed and calibrated aboard the purse seining vessels *Margaret Elizabeth, Island Pride, Dual Venture, Leroy & Barry* and the *Secord* and on two inshore gillnet boats, *Crystal K* and the *Attaboy*. In 2001, acoustic data were collected by recording vessels during both standard fishing excursions and

structured surveys. All data were automatically saved to the system's hard drive and the data downloaded at regular intervals to either a removable hard-drive or tape prior to archiving and analysis by Herring Science Council personnel.

Structured Surveys

Structured surveys, i.e. those that occured at regular intervals and followed a standard protocol, increased in number and the implementation continued to improve in 2001. DFO and the Herring Science Council also signed a Joint Project agreement that defined the minimum number of surveys to be conducted on each spawning ground. These surveys, which are generally scheduled at two week intervals, played an important role in our understanding and perception of 4WX stock. However, sufficient flexibility was built into the process to allow for schedule changes, which increase the number of surveys, and allowed for the investigation of areas of interest or uncertainty. In 2001 structured surveys were conducted on each of the major, and several of the minor, spawning grounds within 4WX, as well as non-spawning aggregations (Figure 1).

Fishing Excursions

Vessels equipped with automated acoustic logging systems activated the units during the search phase of nightly fishing excursions. The activation practice has changed slightly over the past several years. During the early stages of the program fishing captains would turn their system on when they reached the fishing ground and off once they deployed their fishing gear. In 2001, the majority of vessels activate their systems only when they believed there was something worth recording. This greatly reduced the amount of time archiving, editing and analysing. Analyses of acoustic data from approximately 20 non-survey nights were undertaken in 2001. Of these, only 1 night, October 3, was used in the estimation of total SSB. The nights selected for analysis were identified after discussions with individual vessel captains. However, all data were downloaded, archived, edited and stored on CD for future analysis if required.

**Results**

Biomass estimates from industry based acoustic and mapping surveys of individual spawning components of the 4WX herring stock complex form the foundation for the evaluation of stock status. The following provides a summary of the 2001 observations and SSB estimates. The number of surveys scheduled and the number actually completed are summarized in Table 1.

**Bay of Fundy/SWNS**

Scots Bay

Three surveys were conducted in Scots Bay during the 2001 spawning season. The first survey, conducted on the night of July 16, involved 13 commercial purse seiners with 4 acoustic logging systems. The survey began just off Margaretsville following pre-defined northeast transects for approximately 30km up the bay (Figure 2). The majority vessels covered the main spawning area while a few proceeded to document an aggregation of fish northeast of the Isle de Haute. Vessels involved in the predefined area provided good coverage and extended the transects beyond the boundaries to include the fish east of the surveys area (Figure 2). In addition, several vessels including two with recording systems provided excellent coverage of an aggregation of herring northeast of the spawning grounds. The data were analyzed separately for the two locations and the individual biomass estimates summed to obtain a total for the night (Table 3). The coverage area for Area 1 (the predefined spawning grounds) was 325 $km^2$ compared to 15.6 $km^2$ for the aggregation. Comparison of fish location from the non-recording and recording vessels showed an almost identical distribution. Boundaries for the survey area were determined using information from all vessels. Target strength (TS= - 35.69) was estimated from mean length of fish sampled during the survey night and a length-weight relationship of detailed samples collected from Scots Bay during the survey period (Table 2). Length frequency data used to estimate target strength indicated adult fish sizes (Figure 3a). All samples contained ripe or ripe/running fish (Stage 5-6) and consistent of fish within 1 week of spawning. The biomass estimate for Area1 was based on the distance weighted mean Sa from three transects. Estimates of biomass density for the transects ranged from 0.0046 to 0.2212 $kg/m^2$ of herring. The same input parameters for length frequency, weight-length, and TS were used to estimate the biomass in Area 2. Based on 7 transects with a fish density ranging from 0.0004 to 0.238 kg/m2 the biomass estimate for Area 2 was 8,700t (Table 3). The total SSB in Scots Bay on the night July 16, 2001 was estimated to be 87,200t.

The second Scots Bay survey was undertaken on July 31 and involved 5 fishing vessels (2 with automated logging systems) and the portable system aboard the Canadian research Vessel "J.L. Hart". Survey coverage included most of the defined spawning grounds. However, effort of the recording vessels was concentrated in the southern portion survey area where most of the fish aggregations were located (Figure 4). Therefore, to avoid bias associated with the concentration (not selected at random) of transects in the area of fish, the survey area (270 $km^2$) was divided into two strata; the southern portion (104 $km^2$) which contained most of the fish and the northern portion (166 $km^2$) where fish were sparse. Survey boundaries were determined from the information provided by all vessels. Independent estimates of biomass were made for each stratum and then summed to obtain a total for the evening. Input parameters for both strata were obtained from length frequency and detailed samples collected from the area and

TS estimated to be –35.12 (Table 2). Note that the mean size of herring was slightly smaller than the fish observed on July 16th (Table 2). However, the length frequency distribution of samples collected from the area on the survey night showed sizes consistent with adult fish (Figure 3b), and gonad stages were 5-6 or ripe and running. For area 1 the mean density (weighted for distance) of 4 transects, ranging from 0.0195 to 0.389 Kg/$m^2$, was used to estimate an SSB of 48,300t (Table 3). The SSB of 6,100t for area 2 was estimated using the same TS value with transects ranging in fish densities from 0.007 to 0.029 kg/m2 (Table 3). The total estimated SSB of herring for Scots Bay on the night of the July 31st was 54,300t.

The third and final survey for 2001 in Scots Bay was conducted on August 16th by 6 commercial fishing vessels with two acoustic recording systems. The survey provided good coverage of the spawning grounds and encompassed an area of 250 $km^2$ (Figure 5). Six transects were available to represent the area surveyed. Length frequency data (Figure 3c) and a weight-length relationship from samples collected during the survey time were used to estimate target strength (TS= -35.26). All herring sampled were of adult size and detailed samples contained only fish with gonads in an advanced stage (i.e., 5/6) of development. Transect fish concentrations ranged from 0 to 0.054 kg/m2 and when weighted for distance resulted in an SSB of 22,400t.

Combining the SSB's from the three survey nights, the 2001 Scots Bay biomass estimate was 163,900t (Table 4). This represents the third year of surveys with good coverage of this spawning component. Continuation of surveys in the above way will lead to an estimate that can be compared on an inter-annual basis and to an index of abundance in future years.

Trinity Ledge

Prior to 2001 spawning ground surveys of Trinity Ledge involved multiple vessels (10-20) and covered the recommended spawning area (Melvin and Power, 1999). In 2001, a single vessel equipped with an automated acoustic logging system undertook the majority of surveys, and concentrated on only those locations with aggregations of fish. While the surveys documented more herring than in the previous 4 years, it did not provide adequate coverage of the spawning component. No organized multi-vessel surveys were undertaken in 2001. Biomass estimates for Trinity Ledge should be considered a minimum biomass estimate as only a very small portion of the spawning ground was covered. In 2001, we were able to obtain herring sampled from a typical commercial gillnet and from a 4 panel multi-mesh gillnet (Johns Cove Fishery Ltd). The results, which are compared in Figure 6, clearly demonstrate that the smaller mode fish are missed by the former gear and confirm that standard gillnet samples are not representative of the fish present at the time of surveying.

The number of survey nights on Trinity Ledge increased in 2001, but the area (i.e., $km^2$) survey coverage was greatly reduced. The maximum area covered on any a given night was 1.5 $km^2$ (Table 4). In fact, examination of the vessel track and fish location (Figures 7-10) for the nights of August 21, August 28, September 9, and September 11 indicated the occurrence of herring in almost exactly the same place.

Traditionally, biomass estimates for Trinity Ledge were based on a standard 28 cm herring with a TS of –35.5 for a 50 kHz (-35.96 for 200kHz) acoustic system due to the fact that gillnets are known to be size selective. The length frequency of herring collected from commercial gillnet on August 28 is presented in Figure 11. Mean length of fish sampled and their associated target strength values on survey nights are presented in Table 2. Catches by the individual panels of the multi-mesh net are presented in Figure 12.

Biomass estimates on Trinity Ledge were made from acoustic data collected on 4 separate nights in 2001 (Table 4). For August 21 and August 28 the biomass was estimated, using the mean length of the multi-mesh sample, at 1,200t and 6,300t (5,400 + 900 t) respectively. However, given the elapsed time, biomass estimates for September 9 and 11 were based on the standard TS of –35.96 (adjusted for frequency). The biomass estimates were 1,960 and 3,275t respectively (Table 4). Additional information collected by the purse seiner, *Fundy Mistress*, on September 11 indicate no herring in the surrounding area. Acoustic data from the purse seiner were not available due to a malfunction with the portable logging system. Given the required elapsed time of 10-14 days between surveys the spawning stock biomass on Trinity Ledge in 2001 was estimated to be 9,600t from acoustic surveys. In addition, on the night of September 26 the *Silver Harvester* under took a mapping survey of a dense aggregation of roe fish near Trinity Ledge. Based on the log sheet information the school covered an area of 1.3 $km^2$ and was categorized as heavy (i.e. 4000t/km2). The estimate of 5,200t was added to the acoustic SSB for a total of 14,800t (Table 4).

German Bank

The number of structured surveys on German Bank during the 2001 spawning season increased from the four proposed to six due to uncertainty of survey timing and to compensate for the incomplete coverage of some surveys. The primary concern from the fishing industry was that the timing of the scheduled surveys did not represent the peak abundance of individual spawning waves. As well, several surveys were incomplete in that the vessels did not follow the structured survey design. On several occasions vessels surveyed only until fish were encountered then concentrated their effort on the area with fish. The timing between two surveys (September 9 and 13$^{th}$) did not meet the minimum required elapsed time (10 -14 days). Gonad stage data collected from fish samples showed a major decline and rise in percent of mature herring between the two survey dates. Therefore, the two surveys were considered independent and the biomass

estimates from each included in the total SSB (Table 5). Surveys were conducted on August 27, September 9, September 13, September 25 and October 19th. Data from two fishing vessels operating on the bank during the night of October 3 were substituted for an early-October survey as the scheduled one did not occur.

The first spawning ground survey of German Bank in 2001 was conducted on August 27 by 13 purse seining vessels, four with automated acoustic recorders. The main survey area was covered by 10 vessels making two sweeps, north/south and then south/north, of the area along predefined transects (~0.25km apart). In addition, three vessels surveyed an area south west of the starting point where the vessels had been fishing (Figure 13). The total area surveyed was approximately 200 $km^2$ (120 $km^2$ for the survey area and 80 $km^2$ for the fishing area). Herring were distributed throughout the main survey area and concentrated to the west in the fishing area. The data were analyzed for the survey (Box 1) and fishing area (Box 2) separately (Table 5). The boundaries for each box were defined by the outer transects and the fish density estimated from the acoustic transects. The five length frequency samples collected (660 fish measured) on the night of the survey showed a bimodal distribution and the fish ranged in size from 22.5 to 30.5 cm (Figure 14). Mean length was 28.3 cm (Table 2). Biomass estimates were made for each of the areas surveyed and summed to provide a SSB for the survey night. On August 27, 2001 the SSB estimate on German Bank was approximately 33,000t – 28,017 in the main survey area and 5,004t in the fishing area (Table 5).

On September 9, 2001, 14 purse seine vessels, five of which had acoustic logging systems, conducted the second survey on German Bank (Figure 15). The vessels provided excellent coverage of the German Bank spawning grounds, surveying an area of 325 $km^2$. The biomass estimate for this date is considered to be representative of the fish present at the time of the survey. However, the fishing industry did not feel that the observed fish were representative of the fish that had been present or that were present a few days later. Length measurements were obtained from eight samples (1093 fish) which demonstrated a bimodal distribution and a mean length of 27.5 cm (Figure 16). Target strength was estimated from the length frequency and the SSB estimated using all transects within the survey area. Mean transect density ranged from 0.00004 to 0.027 $kg/m^2$ from the acoustic recordings after weighting for length. The SSB was estimated to be 31,000t (Table 5).

Given the fishing industry's view of the September 9$^{th}$ survey, a third survey of German Bank was conducted four days later on September 13$^{th}$. This survey which covered an area of 200 $km^2$ was poorly implemented (Figure 17). The survey started out in an organized manner, but quickly broke-up when a large school of fish was observed. In fact, once fish were observed almost all vessels proceeded to concentrate their effort on the fish. This left a vast area uncovered and the survey incomplete. Length frequency samples showed that a smaller size fish (mean length 26.9 cm) was present on the bank than during the previous survey (Figure 18). However, detailed samples indicate that all fish were mature.

Based on a TS of –35.38 and a total area of 200 $km^2$ the SSB was estimated to be 80,500t (Table 5). Almost 75% of the observed biomass was contained in the single school of fish.

The next survey on German Bank was undertaken as scheduled on the night of September 25, as part of a major initiative to cover Seal Island and Browns Bank as well. Pre-defined transects with start and end points for German Bank and the Seal Island areas were provided to each participating vessel. Six vessels (one recording system) were assigned to German Bank for the survey. The survey, which provided excellent coverage of the area, encompassed 430 $km^2$ of the bank (Figure 19). Survey boundaries were determined from the track of all vessels. Samples indicated a mean length of 27.3 cm with a range of 23.5 to 33.5 cm (Figure 20). The estimated SSB of 12,480t was based on a TS of – 35.49 (Table 5).

Although no survey was undertaken in early October the data, collected by two fishing vessels operating on German Bank on the night of October 3, were used to provide an estimate of SSB during this period. The two vessels concentrated on 28.0 $km^2$ aggregation of spawning herring. Examination of the length frequency distribution and detailed samples indicated the mean length of herring was 26.6 cm and ranged from 23.5 to 32.5 cm. Although the fish covered a broad size range, small fish dominated the catch with a mode of 25.0 cm (Figure 21). All fish in the detailed sample had gonads in stage 5 or stage 6, indicating mature pre-spawning fish. Combining the data from both vessels, the SSB was estimated to be 45,600 using a TS of –35.33 (Table 5).

The final survey of German Bank for the 2001 spawning season was undertaken on the night of October 19. Five vessels, 2 with acoustic recording systems, undertook an excellent survey of the spawning grounds covering approximately 330 $km^2$ (Figure 22). Samples collected from fishing sets after the survey indicated a broad range of fish sizes (19.5 to 32.5), including fish too small to be spawning (Figure 23). Mean length was 23.6cm. Since the detailed sample revealed that all fish were either juvenile or spent the mean length and computed mean weight of 101.0 grams was used for estimating TS. The estimate biomass was 35,600t (Table 5). No fish from this survey were included in the overall SSB for German Bank as the sample indicated non-spawning fish.

In summary, the 2001 spawning stock biomass for German Bank was estimated to be 190,500t. The total SSB is based on the estimate biomass from August 27, September 9, September 13, and October 3 surveys (Table 5). Traditionally, biomass estimates from surveys not separated by a 10-14 day interval, were not considered as part of the cumulative total. However, given that a significant change in the percent of stage 6 fish was observed in the detailed fish samples, it was assumed that a turn-over of spawning herring occurred between September $9^{th}$ and $13^{th}$. Data collected on the September 25 survey (12,380t) were not included in the total SSB. Only 8 days had elapsed between September 25 and

October 3. The 35,600t of fish observed on German Bank on October 19 contained only immature and spent herring, consequently it was not included in the total.

Spectacle Buoy

The Spectacle Buoy spawning ground surveys for 2001 were conducted in two seasons. Traditionally, there has been a spring fishery that harvests roe fish during a short period in June. In 2001 a single gillnetter, equipped with an acoustic logging system, undertook several surveys (June 14th, June 21st and June 28th ) to document the abundance and distribution of these fish. Based on a standard TS of –35.96 because only gillnet samples were available, biomass' of 760t, 800t, and 350t respectively were estimated for aggregations of herring in an area of 0.17 to 0.44 $km^2$ (Table 6). Using the standard approach of 10-14 days separation between surveys the 2001 spring SSB for Spectacle Buoy was estimated to be 1,110t (June 14 and June 28). However, in the fall of 2001 a large aggregation of reproductively mature herring was observed on September 23rd just west of the area where the spring fishery occurred. Both the *Attaboy* and the *Leroy & Barry* were returning from fishing elsewhere when they encountered the large group of herring. Given the dense concentration and wide area of distribution, both vessels activated their logging systems to document the fish. The main difference between the estimates was the area surveyed. The *Attaboy* covered an area of only 1.1 km2 while the *Leroy & Barry* documented the fish over an area of 7.0 $km^2$ (Table 6). Unfortunately, no samples were collected from the aggregation of fish, but roe fish were reported landed from this area between September 24 and 26. Based on the standard TS of –35.50 the estimated biomass was 87,500t. This aggregation of fish was included in the overall SSB for Southwest Nova Scotia (Table 6).

Seal Island

For several years concern has been expressed about the absence of spawning herring in the vicinity of Seal Island. This year a survey was undertaken on September 25th as part of a large-scale coverage of potential spawning areas (Figure 19). The Seal Island survey, which encompassed an area 275 $km^2$, documented 3,200t of herring based on a mean length of 27.3 cm and a TS of –35.49 (Table 7). The estimate biomass was incorporated into the 2001 SSB of the Bay of Fundy/Southwest Nova Scotia stock complex (Table 10).

Browns Bank

Although catches of herring from Browns Bank are considered part of the quota complex, and herring are known to spawn in the area, no spawning ground surveys were undertaken until the fall of 2001 due to limited fishing in the area during spawning season. The first survey was conducted on September 25 when three vessels covered an area of 400 $km^2$ and documented 41,000t of herring (Table 8). No samples were taken on the night of the survey, however, roe fish were landed from the area just before the survey. The standard TS of –35.50 was

used for the estimate. The second observation occurred on the night of October 10th when, during the course of normal fishing operations the Island Pride documented 4,800t of ripe herring in an area of 9.60 $km^2$(Table 8). A TS of -35.02 was estimated from the length frequency sample (mean length 25.4 cm) collected on the fishing night (Figure 24).

Bay of Fundy/SW Nova (Summary)

Biomass estimates from acoustic surveys have been used over the past 5 years to evaluate the status of the Bay of Fundy/Southwest Nova Scotia component of the 4WX herring stock complex. Over the years, estimating the SSB has evolved from a heavy reliance on distribution and abundance estimates from fishing excursions with a 10 day minimum elapsed time, to structured surveys at two week intervals. In 1999 spawning areas were defined and survey protocols established to make the estimates more representative of the actual SSB rather than a minimum observed value. This was accomplished by undertaking a series of surveys that covered most of the spawning area on each of the grounds during the defined spawning season. In addition, because of the reported variability in the movement of spawning fish on and off of the banks, we embarked on studies to investigate indicators for waves of spawners (Power *et. al.*, 2002). In 2001 a major event occurred between September 9 and 13th which resulted in the elapsed time being relaxed for these surveys and the estimates being considered independent of each other. The total observed biomass for the complex was obtained by summing the SSB estimate for each spawning ground. Given the changes, which have occurred over time, the estimated SSB prior to 1999 should not be compared with those reported since. Biomass estimates for a few selected fishing nights not included in the overall SSB are presented in Table 9.

In 2001 the total SSB for the Bay of Fundy/ Southwest Nova Scotia was estimated to be 504,900t, suggesting a slight increase over the previous year (Table 10). However, the total can not be compared directly with previous years. First, approximately, 49,000t must be removed to account for fish observed on Browns Bank and Seal Island which are quota fish, but which have never been surveyed nor included in previous estimates. This reduces the estimate to 455,800t. Furthermore consideration must be given to 87,500t of herring observed near Spectacle Buoy in an area where herring have not been reported/surveyed in recent years. Are these fish part of the German Bank spawning component or is this a new spawning area previously unaccounted for? Regardless, the dramatic decline of observed spawning herring on German Bank is of great concern.

**Nova Scotia Coastal Spawning Component**

Atlantic herring have been reported to spawn in the shallow inshore waters of the bays and inlets along the Atlantic coast of Nova Scotia. Unfortunately, our knowledge of these relatively small coastal populations is limited to a few areas

where there are active commercial fisheries for roe on spawning grounds in the fall of the year. The traditional fishery is for bait in the spring of the year. In 2001, there were two areas where harvesting occurred on spawning grounds of the Nova Scotia coastal stock component; Port Mouton/Little Hope and Jeddore/Eastern Passage. Provision has been made by fishing associations in both areas to undertake acoustic surveys using a gillnet vessel equipped with an automated acoustic logging system. The results of the surveys and logging during fishing nights are presented below.

Little Hope

In 2001 spawning herring appear to have arrived a little earlier near Little Hope/Port Mouton than in the past. As in previous years, an automated acoustic logging system was used to document the distribution of fish. Unfortunately, coverage by the recording vessel was limited to a relative small area (1.7-2.8 $km^2$) on each of the nights that data were collected. It is assumed that the area surveyed represents the distribution of spawning fish in the area. The first of three nights for which biomass estimates were made occurred on September 19 (Figure 25). This is an excellent example of how an aggregation of fish should be surveyed in that the vessel followed a series of parallel transects through the fish. However, no information is available about the surrounding area. The survey documented approximately 14,100t of herring in an area 2.30$km^2$ using the standard TS of -35.96 (adjusted for sounder frequency) (Table 11). Length frequency samples were available for the nights of September 25 and 26 and indicated a mean length of 30.3 cm (Figure 26). These samples could not be used to estimate TS due to the gillnet's selectivity for larger fish. The second night for which data were analyzed was October 7, when 7,200t of spawning herring were documented in 1.68 $km^2$. Again fish sampled on October 11$^{th}$ and 12$^{th}$ could not be used to estimate TS and the standard value was supplemented. The length frequency of herring had a mean length = 30.2 cm. The third and final survey occurred on the night of October 12$^{th}$ and recorded 3,700t in 2.84 $km^2$. Conforming to the standard practice of summing biomass estimates with 10-14 days elapsed time between surveys resulted in a 2001 SSB estimate for Little Hope of 21,300t.

Eastern Passage

Acoustic surveys undertaken by the Eastern Shore Fishermen's Protective Association in 2000 encountered a number of technical problems, which limited the confidence in biomass estimates produced by the logging system. In 2001 these problems were corrected and the system transferred to the *Crystal Kay* for surveying. Between September 24 and October 13 the Crystal Kay recorded 10 nights (including 1 survey) of data on herring abundance and distribution in the Jeddore/Eastern Passage area. In all cases the data were collected following the defined protocol and provided good coverage of the fish surveyed. However, on most nights the amount of fish observed was relatively small in relation to the survey of October 1 (Table 12). Consequently, biomass estimates were made for

only three nights; October 1, 8, and 13th. Although length frequency data from the gillnets were available (Figure 28), the standard TS of –36.96 was used to estimate biomass. On October 1, 17 vessels participated in a survey of the area in conjunction with the Crystal Kay (Figure 27). The biomass estimate from the mapping survey was 11,000t compare to 15,000t for the acoustic estimate. Keeping with our practice of summing surveys the estimate for October 13 was added to October 1 for a 2001 SSB of 16,700t (Table 16). This is the highest observed SSB for this spawning area to date.

Glace Bay

On the night of September 30, 2001 thirteen boats conducted a single mapping survey in the vicinity of Glace Bay. The vessels broke into two groups to cover the two aggregations of spawning fish (Figure 29). Based on the information provided in the survey data sheets, it was estimated that approximately 11,150t were observed in the northern group and 10,030t in the southern group. No length frequency samples were available for the night of the survey. Length frequencies collected from gillnet catches on September 4, 10, and 24th were pooled to demonstrate the size composition (Figure 30). Mean length of the catch was 32.2cm.

Bras d'Or Lakes

Coverage of the Bras d'Or Lakes herring spawning grounds was limited to 3 mapping surveys in the spring of 2001 and no biomass estimates of the observations were made. The first survey, undertaken on April 28 in West Bay was greater in extent than in the previous year but showed less fish. The second survey on April 29 of East Bay and the northern portion of Bras d'Or Lake, which covered a greater area than in 2000, also suggested less fish. Most herring were found off Eskasoni, in East Bay. A third survey, conducted on April 30 around Baddeck, covered less area and observed fewer fish than in 2000. No survey of St. Peters inlet, where fish were observed in previous years, was undertaken in 2001 (Figure 31). Only four length frequencies samples were collected from commercial gillnets in the spring of 2001 (Figure 32). These included, two samples from Black Rock (62 fish), one from Little Harbour (14 fish) and one from MacRae's (228 fish). The mean length of 33.7 cm was similar to those collected in Bras d'Or Lakes in recent years. However the similarity may be due to the selectivity of the fishing gear. No detailed samples were obtained for investigation of spring/fall spawner composition.

**Offshore Scotian Shelf Component**

Fleet activity/catch in the spring/early summer fishery on the offshore banks of the Scotian Shelf increased from 2,100t in 2000 to approximately 11,700t in 2001. The fishery began in May, peaked in June and approached the 12,000t allocation in

early July. Examination of the acoustic data collected from fishing excursions did not reveal sufficient quantities of fish to justify an increase in the allocation. On July 3-4 an extensive survey of the outer banks was undertaken by the industry from the Patch to Roseway Bank to document the distribution and abundance of herring (Figure 33). While herring were observed scattered throughout the survey area the largest concentrations were observed around Roseway Bank. The total area covered was 101km$^2$ with a mean density 1.435 kg/m$^2$ (Table 14). The biomass estimate of non-spawning fish for the outer banks, based on a mean length of 27.0 cm and a TS of -35.4, was 145,000t (Figure 34). No other estimates from fishing excursions were made for the outer Banks given the limited coverage and small quantities observed.

**Chebucto Head (January 2001)**

Each year in January since 1998, DFO and the herring industry, have undertaken an acoustic survey of a large over-wintering aggregation of herring just off Chebucto Head, N.S. The purpose of the acoustic survey has been to estimate the abundance of herring and to investigate the movement, using mark/recapture methods, of mixed spawning origin fish. Tagging returns during the 1999 to 2001 fishing season indicated that a portion of the fish originated from spawning areas in Southwest Nova, but the returns provided little information on the possible mixture with other components (Power et al., 2002). This was primarily due to the fact that catches of herring in areas other than SW Nova, represented less than 1% of the SW Nova/Bay of Fundy landings. Maximum biomass estimates were 483,000t, 103,000t and 158,000t in January of 1999, 2000 and 2001, respectively (Melvin et. al. 2001).

In January of 2002 surveys were conducted on the overwintering aggregations of herring on the nights of January 9 and 10 off Chebucto Head. Unfortunately, the herring observed did not cover as an extensive area nor were they as densely concentrated as in previous years. Consequently, only the data from January 9 were analyzed in detail. Two vessels participated in the survey: the *Margaret Elizabeth* and the *Canada 100*. Figure 35 shows the vessel track of the *Margaret Elizabeth* covering an area of approximately 30 km$^2$ (Table 15). In addition, the *Canada 100* covered another 5 km2 just north of the *Margaret Elizabeth*. Prior to surveying it was agreed that the seiner fleet would be compensated for surveying and tagging at a rate of 100t/night, that 50,000-70,000t must be observed before fish could be removed and that no fishing would occur until survey and tagging were complete for the night. Maximum removals were again set at 1.5 % of observed biomass to a maximum of 5,000t. The January 9$^{th}$ biomass estimate was 20,300t in 35.0 km$^2$ using a mean length of 24.9 cm and a TS of –33.90 (Table 16) (Figure 36). The original estimate of 27,000t was based on the standard TS of –35.5 for a 28cm fish.

## Discussion

During 2001 Industry based acoustic surveys were conducted on the 3 major spawning locations (Scots Bay, Trinity Ledge and German Bank) and several minor 4WX spawning components to provide an estimate of SSB for the stock complex. In addition, the survey series was expanded to include a single night around Seal Island and Browns Bank. A large aggregation of spawning herring was also documented just west of Spectacle Island. This is the fifth year of surveying and the third year where the biomass estimates from these surveys have played a significant role in the estimate of stock abundance. As in previous years, there is a possibility that spawning fish were outside survey coverage for any given survey and the potential for the series of scheduled surveys to miss a wave(s) of spawners using a two-week interval between surveys. Consequently, the results must be considered an estimate of minimum SSB. Last year, effort was directed toward estimating the timing of spawning waves onto German Bank. The results of the study are presented and the implications on surveys are discussed in Appendix II of Power et. al, 2002.

Acoustic surveys of major spawning areas in the Bay of Fundy/ Southwest Nova Scotia in 2001 were generally well organized, regularly scheduled, contained several automated acoustic logging vessels, covered relatively large areas and followed established survey protocol. However, there were a few nights when the surveys were cut short and/or effort concentrated on the location of the largest aggregation of fish resulting in incomplete coverage of the recommended spawning area.

In Scots Bay sufficient time (~14 days) elapsed between surveys to meet the turnover requirement and coverage was excellent. Consequently, the biomass' observed on the three survey nights were added to provide an SSB of 163,900t for the component. This marks the second year in which an increase in SSB was documented and a dramatic improvement over 1999 when only 40,972t were observed.

Surveying of Trinity Ledge improved in 2001, but did not provide adequate coverage of the area to characterize the spawning group. In fact, the maximum area surveyed was only 1.53 $km^2$ where the recommended area was in the order of 250$km^2$. On all four nights that herring were documented on Trinity Ledge a small aggregation of fish was recorded in almost exactly the same location. The recording vessel did, however, follow the protocol for surveying a school of fish, and editing and analysis of the area covered was easily accomplished. The surveys of Trinity Ledge need to be expanded to ensure all spawning fish are documented. Another consideration for Trinity Ledge is an apparent extension of the spawning season. Traditionally, the spawning has been considered to occur between August 15$^{th}$ and September 15$^{th}$ when the area is closed to purse seine fishing. This year a purse seiner fishing on the ledge documented 5,700t of roe fish on September 26$^{th}$. Sampling also improved in 2001 in that the industry

experimented with a multi-mesh gillnet to collect a representative sample of fish present at the time of surveying. Examination of the size of fish present in the variable mesh-size net indicated the presence of smaller fish than the commercial net would collect. It is recommended that in the future the multi-mesh net be used to collect a fish sample during gillnet surveys.

For the past two years the advice regarding the harvesting of spawning fish has been to "fish with caution" on Trinity Ledge given the low observed biomass. In 2001 the observed biomass increased from 600t to 14,800t, the largest SSB since 1997. However, a large portion of the increase is attributed to an observation made outside the normal survey period. Given the much larger historical contribution of the area to total landings, it is recommended that "fish with caution" approach continue until a further improvement is observed.

The 2001 SSB for German Bank, the largest component of the stock complex, is cause for concern. Regardless of how the numbers are added there appears to have been a significant decline in the abundance of spawning fish on the traditional areas of the bank. There have been a number of discussions on the reason for our observations including the missing of fish during the surveys and incomplete coverage. Subsequently, the survey data were reviewed in light of the turnover study to examine if and where the required elapsed time might be relaxed. This, in part, was due to the fishing industry's view that the surveys did not reflect the abundance of herring observed just before or after the survey. Based on evidence found in the variation of the proportion of stage 6 fish in landings, the surveys of September 9 and 13$^{th}$ were considered independent as it appeared that a turn over of fish had occurred. Unfortunately, there is insufficient evidence to determine when other waves of spawning herring occurred and the 10-14 days rule was applied for surveys after the 13$^{th}$. The documented SSB on German Bank for 2001 was 190,500t using our traditional approach. This represents a decline of approximately 160,000t. Even if the biomass observed west of Spectacle buoy is included in the total for German Bank (278,000t), there is a decline of almost 80,000t. A "fish with caution" approach should also be used for German Bank until it is determined that 2001 was simply an anomalous year or whether there has been an erosion of the spawning component.

The SSB of the Bay of Fundy/ SW Nova Scotia component of the 4WX stock complex increased slightly (8%) from 2000. The total observed SSB was 504,900t. However, the increase was the result of adding new survey areas to the component, i.e., Seal Island and Browns Bank and a large aggregation west of Spectacle Buoy. If these estimates were not included in the total, the SSB actually declined by 95,000t, all of which can be attributed to a decline on German Bank.

The Nova Scotia coastal spawning component of the 4WX stock complex is characterized by acoustic surveys of two relatively small spawning grounds – Little Hope/Port Mouton and the Jeddore/Eastern Passage area. This is the second year acoustic surveys and data are available for both areas. Technical problems

encountered in previous years have been overcome. Biomass estimates of herring spawning in both areas increased to 21,300t for Little Hope and 16,700t for Eastern Passage (Table 16). The increases are likely attributable to improved coverage and survey design. A single mapping survey in the vicinity of Glace Bay showed approximately 21,200t of spawning herring. No biomass estimates were made for the Bras d'Or Lakes.

**References**


Black, G. 2000. ACON Data Visualization Software Version 8.29. Department of Fisheries and Oceans, Halifax, N.S. www.mar.dfo-mpo.gc.ca/science/acon

Foote, K.G. 1987. Fish target strengths for use in echo integrator surveys. J. Acoust. Soc. Am. 82: 981-987.

Melvin, G.D., K.J. Clark, F.J. Fife, M.J. Power, S.D. Paul, and R.L. Stephenson. 1998. Quantitative acoustic surveys of 4WX herring in 1997. DFO Canadian Stock Assessment Secretariat Res. Doc. 98/81: 25p.

Melvin, G.D. and M.J. Power. 1999. A proposed acoustic survey design for the 4WX herring spawning components. DFO Canadian Stock Assessment Secretariat Res. Doc. 99/63: 15p.

Melvin, G.D., T. Scheidl, F.J. Fife, M.J. Power, K.J. Clark, and R.L. Stephenson. 1999. Evaluation of the 1998 4WX herring acoustic surveys. 1999. DFO Canadian Stock Assessment Secretariat Res. Doc. 99/180: 32p.

Melvin, G.D., T. Scheidl, F.J. Fife, M.J. Power, K.J. Clark, R.L. Stephenson, C. L. Waters and S. D. Arsenault. 2000a. Summary of the 1999 herring acoustic surveys in NAFO Divisions 4WX. DFO Canadian Stock Assessment Secretariat Res. Doc. 2000/066: 40p.

Melvin, G.D., R.L. Stephenson, M. J. Power, F. J. Fife and K. J. Clark. 2001. Industry acoustic surveys as the basis for in-season decisions in a co-management regime. In F. Funk, J. Blackburn, D. Hay, A.J. Paul, R. Stephenson, R. Toresen, and D. Witherell(eds.) 2001Herring Expectations for a new millennium. University of Alaska Sea Grant, AK-SG-01-04, Fairbanks. 675-688.

Melvin, G.D., M.J. Power, F.J. Fife, K.J. Clark, and R.L. Stephenson. 2001. Summary of 2000 herring acoustic surveys in NAFO Divisions 4WX. DFO Canadian Stock Assessment Secretariat Res. Doc. 2001/56. 41p

Power, M.J., R.L. Stephenson, L.M. Annis, F.J. Fife, K.J. Clark and G.D. Melvin. 2002. 2002 evaluation of 4VWX herring. DFO Canadian Stock Assessment Secretariat Res. Doc. 2002/45.103p.

Stephenson, R.L., M.J. Power, F.J. Fife, G.D. Melvin, and S.D. Paul. 1997. 1997 Evaluation of the stock status of 4WX herring. DFO Atlantic Fish. Res. Doc. 97/61: 28p.

Stephenson, R.L., M.J. Power, K.J. Clark, G.D. Melvin, F.J. Fife and S.D. Paul. 1998. 1998 evaluation of 4VWX herring. DFO Canadian Stock Assessment Secretariat Res. Doc. 98/52: 58p.

Table 1. Summary of the 2001 herring spawning ground surveys scheduled and undertaken within the 4WX stock complex.

| Spawning Ground | Surveys Scheduled | Surveys Completed |
|---|---|---|
| Scots Bay | 3 | 3 |
| Trinity Ledge | 3 | 3 |
| German Bank | 4 | 6* |
| Eastern Passage | 1 | 3* |
| Port Mouton | 1 | 3* |

* Surveys include biomass estimate(s) from fishing days which were used in the estimation of SSB for the spawning component.

Table 2. Summary of fish sampled, length/weight relationship, target strength estimate of samples, and target strength estimate for a 28cm herring using the length/weight equation by location date and survey.

| Date | Location | Number Samples | Number Fish | Mean Len (cm) | Mean Weight (gm) | Slope | Intercept | Target Strength | Wt 28cm Fish | TS 28cm Fish |
|---|---|---|---|---|---|---|---|---|---|---|
| 16-Jul | Scots Bay | 8 | 1040 | 27.52 | 181.03 | 3.113 | -2.224 | -35.69 | 191.05 | -35.768 |
| 31-Jul | Scots Bay | 2 | 207 | 26.25 | 145.26 | 3.014 | -2.115 | -35.12 | 176.52 | -35.425 |
| 16-Aug | Scots Bay | 8 | 1368 | 26.22 | 149.13 | 3.350 | -2.578 | -35.26 | 185.77 | -35.647 |
| 23-Aug | Trinity Ledge** | 4 | 328 | 27.44 | 176.91 | 3.117 | -2.235 | -36.07* | 188.42 | -35.708 |
| 24-Aug | Trinity Ledge# | 1 | 153 | 29.55 | 222.86 | 3.117 | -2.235 | -36.07* | 188.42 | -35.708 |
| 28-Aug | Trinity Ledge# | 1 | 214 | 28.46 | 196.25 | 3.117 | -2.235 | -36.07* | 186.15 | -35.660 |
| 11-Sep | Trinity Ledge | 0 | - | - | - | - | - | -35.96 | | |
| 27-Aug | German Bank | 6 | 660 | 28.30 | 191.56 | 3.206 | -2.370 | -35.71 | 186.15 | -35.66 |
| 09-Sep | German Bank | 8 | 1093 | 27.45 | 174.71 | 3.490 | -2.770 | -35.55 | 187.22 | -35.68 |
| 13-Sep | German Bank | 7 | 844 | 26.86 | 160.84 | 3.43 | -2.700 | -35.38 | 185.60 | -35.64 |
| 25-Sep | German Bank | 3 | 343 | 27.20 | 169.06 | 3.60 | -2.94 | -35.49 | 187.72 | -35.69 |
| 25-Sep | Browns Bank | 0 | - | - | - | - | - | -35.50 | - | - |
| 03-Oct | German Bank | 1 | 108 | 26.57 | 155.46 | - | - | -35.33 | 187.72 | -35.69 |
| 11-Oct | Browns Bank | 1 | 89 | 25.80 | 139.84 | - | - | -35.12 | 187.72 | -35.69 |
| 19-Oct | German Bank | 1 | 99 | 25.41 | 132.39 | - | - | -35.02 | - | - |

* TS adjust by -0.46 dB to account for difference in acoustic signal from 120 kHz system.

** Sample collected by multi-mesh gillnet.

# Gillnet sample – use TS from August 23, 2001

Table 3. Summary of the 2001 Scots Bay spawning ground acoustic survey data and biomass estimates for scheduled surveys. The total SSB for the spawning component is obtained by summing the biomass estimates. Target strength was estimated for length frequency samples collected from the area on the night of the survey. Reverse text color identifies surveys used to estimate total SSB (rounded to nearest 100t) for the spawning component.

| Location | Date | Area (km2) | Weighted Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **Scots Bay** | | | | | | | | |
| Area 1 | July 16 | 325.0 | -41.860 | 0.2414 | 27.52 | -35.69 | 78 458 | 22,594 |
| Area 2 | July 16 | 15.6 | -38.210 | 0.5591 | 27.52 | -35.69 | 8 722 | 536 |
| Area 1 | July 31 | 104.0 | -38.459 | 0.4640 | 26.25 | -35.12 | 48 256 | 9,525 |
| Area 2 | July 31 | 166.0 | -49.500 | 0.0365 | 26.25 | -35.12 | 6 061 | 1,786 |
| | Aug 16 | 250.0 | -45.739 | 0.0896 | 26.22 | -35.26 | 22 401 | 2,300 |
| | | | | | | Total | 163,900 | |

Table 4. Summary of the 2001 Trinity Ledge acoustic survey results and SSB biomass estimate. The survey area covered only a small portion of the spawning ground. No mapping surveys were undertaken during the 2001 fishing season. Reverse text color identifies surveys used to estimate total SSB (rounded to nearest 100t) for the spawning component.

| Location | Date | Area (km2) | Weighted Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **Trinity Ledge** | | | | | | | | |
| | 21-Aug | 1.16 | -35.917 | 1.036 | 27.44 | -36.07 | 1,202 | 352 |
| Box 1 | 28-Aug | 0.71 | -27.229 | 7.657 | 27.44 | -36.07 | 5 437 | 2,050 |
| Box 2 | 28-Aug | 0.20 | -29.611 | 4.425 | 27.44 | -36.07 | 885 | 350 |
| | 09-Sep | 1.10 | -33.451 | 1.782 | - | -35.96* | 1,960 | 408 |
| | 11-Sep | 1.53 | -33.573 | 1.733 | - | -35.96* | 3 275 | 2,599 |
| Fishing | 26-Sep | 1.30 | - | 4.000 | - | | 5 200** | |
| | | | | | | Total | 14,800 | |

*TS adjusted for difference in 120kHz
** Paper survey by Silver Harvester

Table 5. Summary of the 2001 German Bank spawning ground acoustic survey results and SSB biomass estimates from structured surveys. Dates with more than one estimate include the main survey area (Box 1) and other areas where fish were observed (Box 2). In this case the biomass was summed for the day. Reverse text color identifies surveys used to estimate total SSB (rounded to nearest 100t) for the spawning component.

| Location | Date | Area (km2) | Weighted Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **German Bank** | | | | | | | | |
| Box 1 | Aug 27 | 120 | -42.029 | 0.234 | 28.30 | -35.71 | 28,017 | 1,083 |
| Box 2 | Aug 27 | 80 | -47.748 | 0.063 | 28.30 | -35.71 | 5,004 | 1,561 |
| | Sept 09 | 325 | -45.751 | 0.096 | 27.55 | -35.55 | 31,026 | 1,191 |
| | Sept 13 | 200 | -39.314 | 0.404 | 26.86 | -35.38 | 80,847 | 3,659 |
| GB | Sept 25 | 430 | -50.881 | 0.029 | 27.29 | -35.49 | 12,380 | 1,751 |
| Fishing | Oct 03 | 28.0 | -33.209 | 1.623 | 26.57 | -35.33 | 45,600 | 14,995 |
| | Oct 19 | 330 | -44.468 | 0.127 | 27.29 | -35.49 | 35,613 | 18,874 |
| | | | | | | Total SSB | 190,500 | |

Table 6. Summary of the 2001 Spectacle Buoy acoustic survey results and SSB biomass estimate. No mapping surveys were undertaken during the 2001 fishing season.

| Location | Date | Area (km2) | Weighted Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **SpectacleBuoy** | | | | | | | | |
| | 14-Jun | 0.17 | -29.054 | 4.905 | - | -35.96* | 759 | - |
| | 21-Jun | 0.44 | -32.973 | 1.990 | - | -35.96* | 786 | 406 |
| | 28-Jun | 0.18 | -32.345 | 2.300 | - | -35.96* | 351 | 131 |
| | 23-Sep | 1.10 | -23.339 | 18.285 | - | -35.96* | 20,113 | 5,470 |
| L&B | 23-Sep | 7.0 | -24.530 | 12.503 | - | -35.50 | 87,521 | - |
| | | | | | | Total SSB | 88,600 | |

* No samples - standard TS adjusted for frequency difference.

Table 7. Summary of the 2001 Seal Island acoustic survey results and SSB biomass estimate.

| Location | Date | Area (km2) | Weighted Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **Seal Island** | | | | | | | | |
| | 25-Sept | 275 | -54.768 | 0.012 | 27.50 | -35.49 | 3,248 | 529 |
| | | | | | | Total SSB | 3,200 | |

Table 8. Summary of the 2001 Browns Bank acoustic survey results and SSB biomass estimate.

| Location | Date | Area (km2) | Weighted Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **Browns Bank** | | | | | | | | |
| | 25-Sept | 400 | -45.393 | 0.102 | - | -35.50* | 40,996 | 10,791 |
| | 10-Oct | 9.60 | -38.019 | 0.560 | 25.41 | -35.02 | 4,809 | 1,875 |
| | | | | | | Total SSB | 45,800 | |

* No Samples Standard TS used to estimate biomass.

Table 9. Summary of SSB estimates from non-structured survey data (i.e. fishing excursions) from the Bay of Fundy/Southwest Nova Scotia for 2001. The standard TS of –35.5 was used to estimate biomass for all fishing nights, except Pollock Point.

| Location | Date | Area ($km^2$) | Weighted Sa ($dB/m^2$) | Density ($kg/m^2$) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| Pollock Point | 26-Jul | 8.58 | -28.24 | 5.09 | 27.8 | -35.31 | 43,627 | 32,083 |
| German Bank | 29-Jul | 35.59 | -39.85 | 0.3677 | - | -35.50 | 13,086 | 3,138 |
| German Bank | 30-Jul | 36.48 | -41.08 | 0.2766 | - | -35.50 | 10,089 | 2,613 |
| German Bank | 31-Jul | 216.98 | -50.535 | 0.0314 | - | -35.50 | 6,807 | 36,284 |
| German Bank | 2-Aug | 4.52 | -25.494 | 10.01 | - | -35.50 | 45,262 | 26,766 |
| German Bank | 6-Aug | 12.45 | -32.824 | 1.85 | - | -35.50 | 23,053 | 14,464 |
| German Bank | 9-Aug | 44.72 | -56.26 | 0.0084 | - | -35.50 | 376 | 174 |
| German Bank | 12-Aug | 77.41 | -48.27 | 0.0528 | - | -35.50 | 4,089 | 2,418 |
| Scot's Bay | 19-Aug | 3.92 | -30.81 | 2.95 | - | -35.50 | 11,554 | 3,558 |

Table 10. Summary of the minimum observed spawning stock biomass for each of the surveyed spawning grounds in the Bay of Fundy/SW Nova component of the 4WX stock complex.

| Location | 1997 Observed | 1998 Observed | 1999 Observed | 2000 Observed | 2001 Observed |
|---|---|---|---|---|---|
| **Scots Bay** | 160,168 | 72,473 | 40,972 | 106,316 | 163,900 |
| **Trinity Ledge** | 23,000 | 6,762 | 3,885 | 621 | 14,800 |
| **German Bank** | 370,400 | 440,704 | 460,823 | 356,372 | 190,500* |
| **Spectacle B** - Spring | 15,000 | 1,329 | 0 | 0 | 1,100 |
| Sub-Total | 568,500 | 521,268 | 505,680 | 463,309 | 370,300 |
| Additional: | | | | | |
| Spectacle B - Fall | | | | | 87,500 |
| Seal Island | | | | | 3,300 |
| Browns Bank | | | | | 45,800 |
| Total | | | | | 506,900 |

* German Bank Sept 23 not included

Table 11. Summary of the 2001 Little Hope/Port Mouton acoustic survey results and SSB biomass estimates. Note the standard TS was corrected to account for a change in frequency from 50 kHz to 120 kHz. Reverse text color identifies surveys used to estimate total SSB (rounded to nearest 100t) for the spawning component.

| Location | Date | Area (km2) | Weighted Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **Little Hope** | | | | | | | | |
| Survey | Sep 19 | 2.30 | -28.077 | 6.143 | - | -35.96 | [redacted] | 4,473 |
| Survey | Oct 7 | 1.68 | -29.644 | 3.852 | - | -35.96 | [redacted] | 2,230 |
| Survey | Oct 12 | 2.84 | --34.840 | 1.294 | - | -36.96 | 3,675 | 975 |
| | | | | | | Total SSB | 21,300 | |

Table 12. Summary of the 2001 Eastern Passage acoustic survey results and mapping SSB biomass estimates. Reverse text color identifies surveys used to estimate total SSB (rounded to nearest 100t) for the spawning component.

| Location | Date | Area (km2) | Weighted Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **Eastern Shore** | | | | | | | | |
| Acoustic | Oct 1 | 15.0 | -35.948 | 1.003 | - | -35.96 | [illegible] | 3,610 |
| Mapping | Oct 1 | 118 | - | - | | | 11,028 | |
| Acoustic | Oct 8 | 0.44 | -25.260 | 11.74 | - | -35.96 | 5,205 | - |
| Acoustic | Oct 13 | 1.15 | -34.293 | 1.468 | - | -35.96 | [illegible] | - |
| | | | | | | Total SSB | 16,700 | |

Table 13. Summary of mapping survey undertaken in the vicinity of Glace Bay on the night of September 30, 2001. The survey covered two aggregations of spawning herring. The estimates were pooled for the SSB.

| Location | Date | Area (m2) | Mean Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **Glace Bay** | | | | | | | | |
| Group A | Sept 30 | 40.0 | - | - | 32.17 | - | 10,029 | - |
| Group B | Sept 30 | 60.6 | - | - | 32.17 | | 11,149 | - |
| Combined | Sept 30 | 100.6 | - | - | 32.17 | | 21,178 | - |

Table 14. Summary of acoustic logging data collected during a survey from the Patch to Roseway Bank in the spring of 2001. Fishing night data were not analyzed due to the small amount of fish observed.

| Location | Date | Area (m2) | Mean Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| **RosewayBank** Survey | July 4 | 101 | -33.831 | 1.435 | 26.97 | -35.40 | 144,956 | 102,641 |

Table 15. Summary of the 2002 winter acoustic surveys conducted off Chebucto Head, N.S. on the night of January 9. Vessels involved included the *Margaret Elizabeth (ME) and the Canada 100 (PT)* which were equipped with the portable acoustic logging system.

| Location | Date | Area (km2) | Weighted Sa (dB)/m2 | Density (kg/m2) | Mean Length | Target Strength | Biomass (t) | Standard Error |
|---|---|---|---|---|---|---|---|---|
| Chebucto Head | | | | | | | | |
| ME | 9-Jan | 30.0 | -43.533 | 0.109 | 24.91 | -33.90 | 3,264 | 946 |
| PT | 9-Jan | 5.0 | -28.581 | 3.403 | 24.91 | -33.90 | 17,016 | 6,806 |
| ME & PT | 9-Jan | 35.0 | -31.021 | 2.74 | 24.91 | -33.90 | | - |

Table 16. Summary of the estimated biomass for locations outside the Bay of Fundy/Southwest Nova Scotia quota area. All areas except the Scotian Shelf are for individual spawning grounds and are estimates of SSB.

| Area | 1999 | 2000 | 2001 |
|---|---|---|---|
| Little Hope | 14,600 | 5,200 | 21,300 |
| Eastern Passage | 9,500 | 10,870 | 16,700 |
| Bras d'Or Lakes | - | 70 | - |
| Glace Bay | - | - | 21,200 |
| Scotian Shelf | 22,300 | 85,600 | 145,000 |

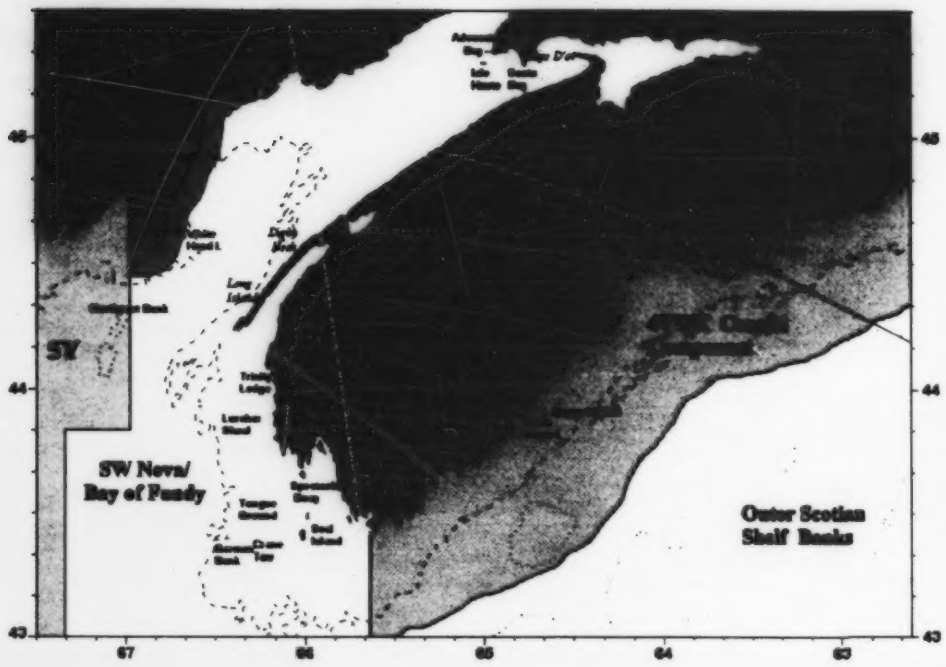


Figure 1. Map of the major spawning areas within the 4WX herring stock complex.

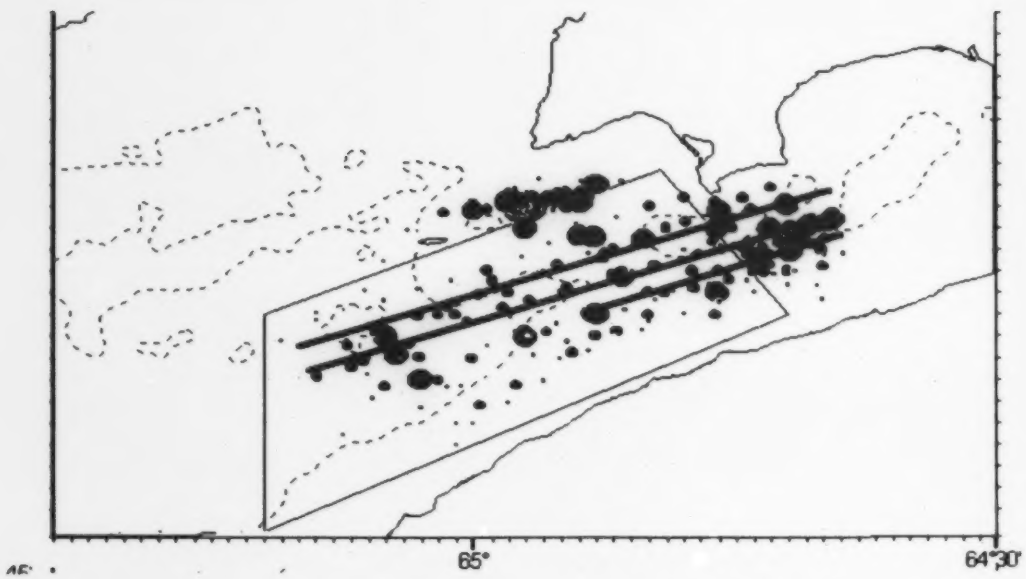


Figure 2. Summary of the vessel track and herring distribution for the July 16, 2001 survey of the Scots Bay spawning ground. The dark lines indicate the acoustic transects.

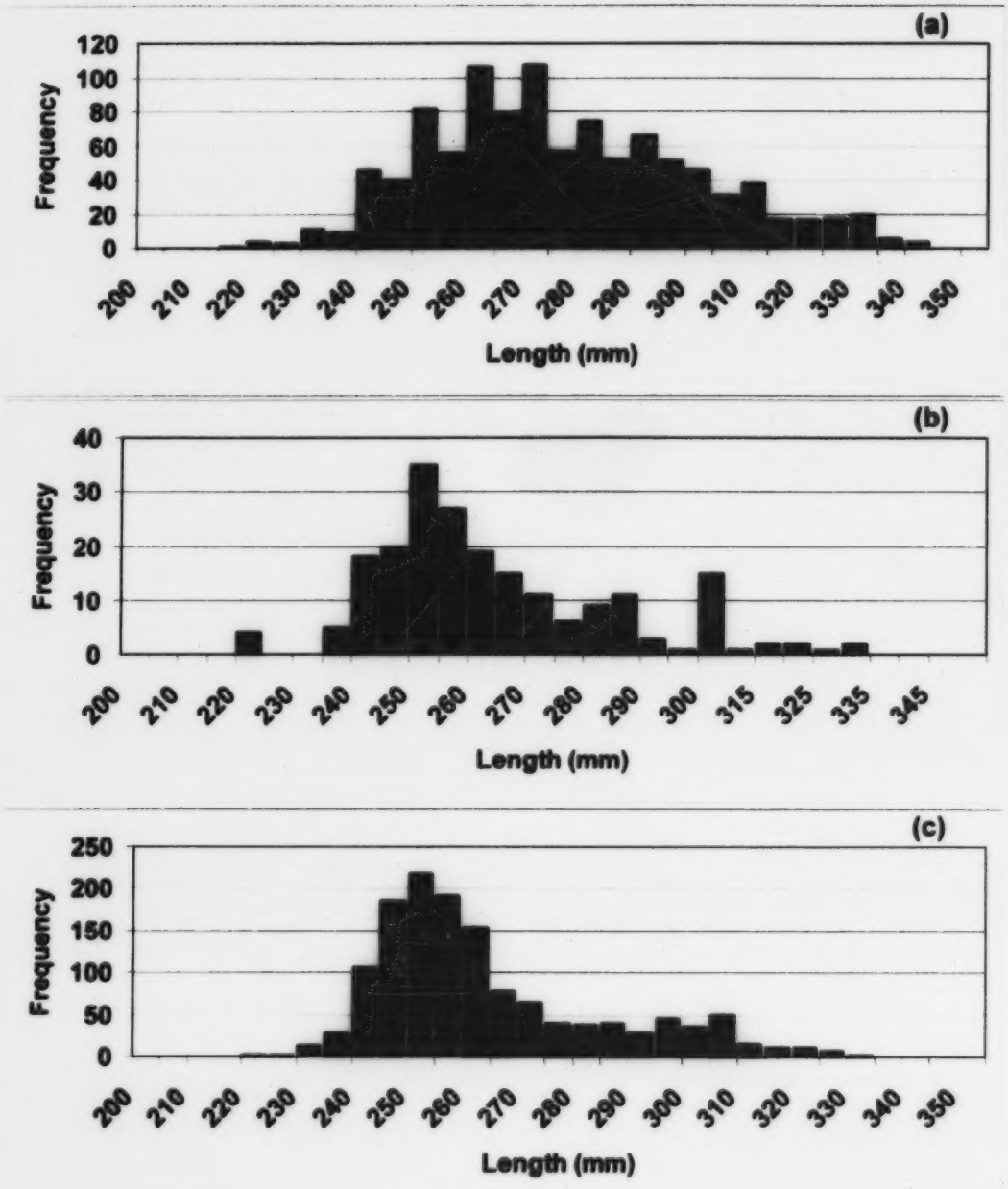


Figure 3. Length frequency of herring samples collected in Scots Bay for the survey nights of July 16 (a), July 31(b), and August 16(c), 2001.

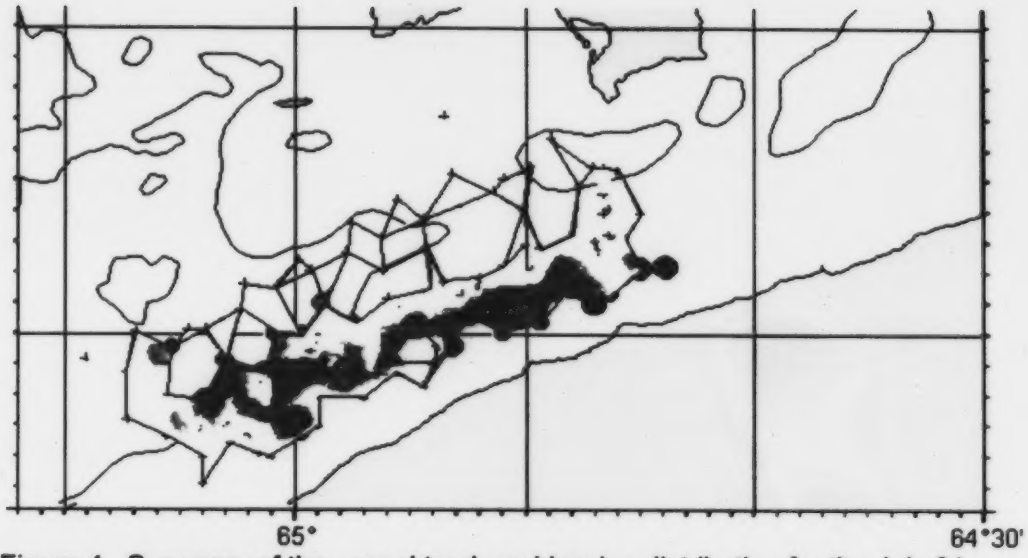


Figure 4. Summary of the vessel track and herring distribution for the July 31, 2001 Scots Bay survey. Data for both recording and non-recording vessels are presented.

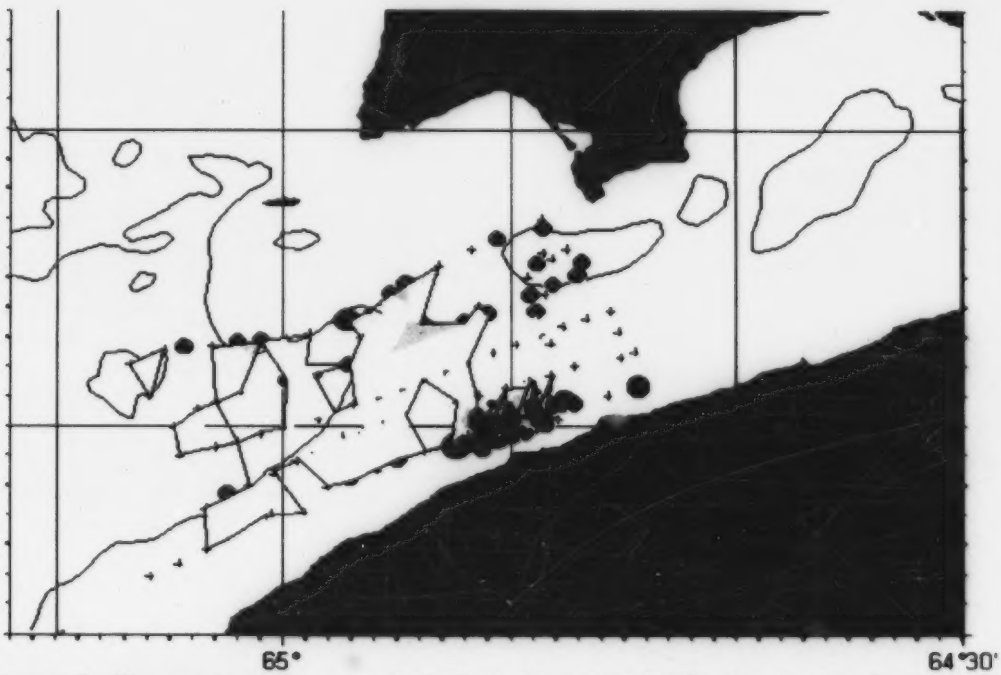


Figure 5. Summary of the vessel track and herring distribution for the August 16, 2001 Scots Bay survey. Data for both recording and non-recording vessels are presented.

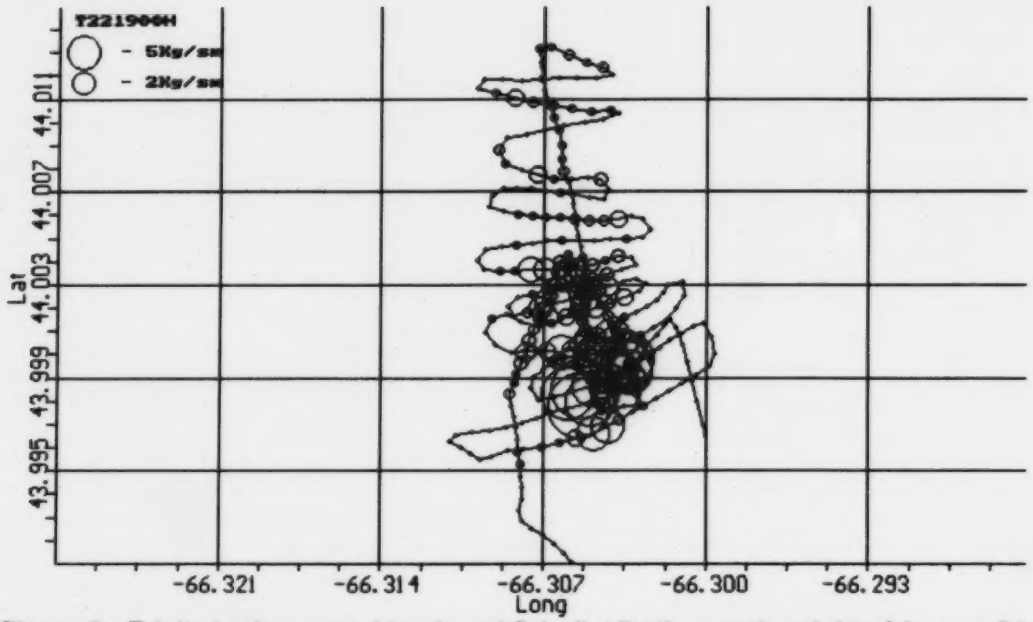


Figure 6. Trinity Ledge vessel track and fish distribution on the night of August 21, 2001. Note the survey coverage is only 1.16 $km^2$ compared to the recommended spawning ground area is 241 $km^2$.

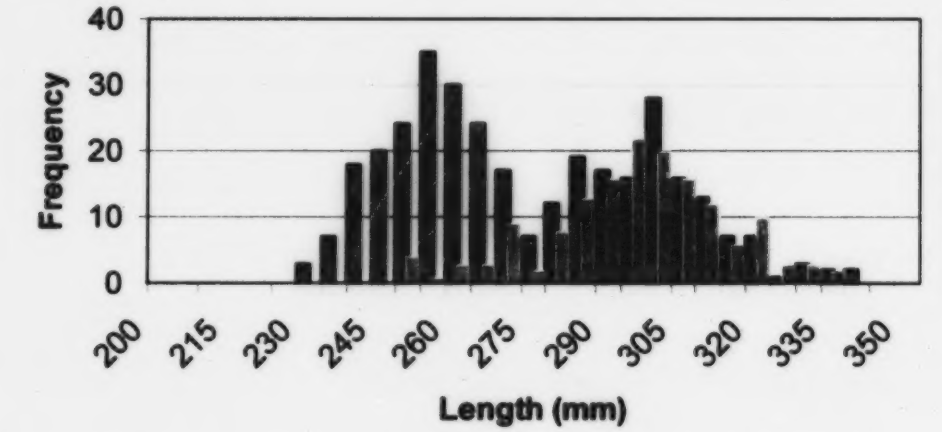


Figure 7. Length frequency distribution of herring collected on Trinity Ledge August 23, 2001 by commercial fishing gear (gray) and August 24, 2001 by a multi-mesh experimental net (dark). Mean length for the former was 29.55cm versus 27.44cm for the latter.

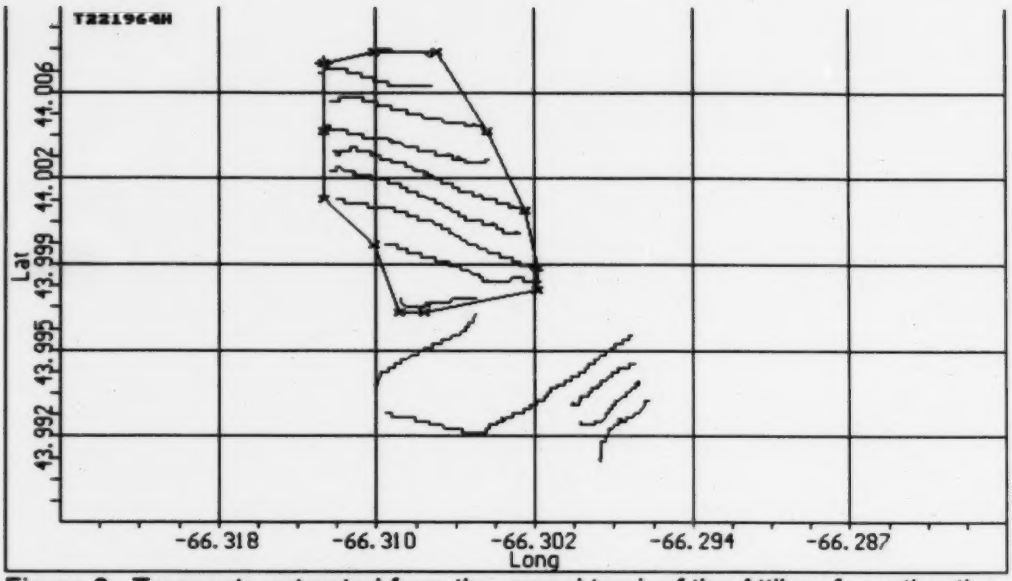


Figure 8. Transects extracted from the vessel track of the Attiboy for estimation of spawning stock biomass on Trinity Ledge, August 28, 2001. The fish were grouped into 2 areas. Total survey coverage was 0.91 $km^2$.

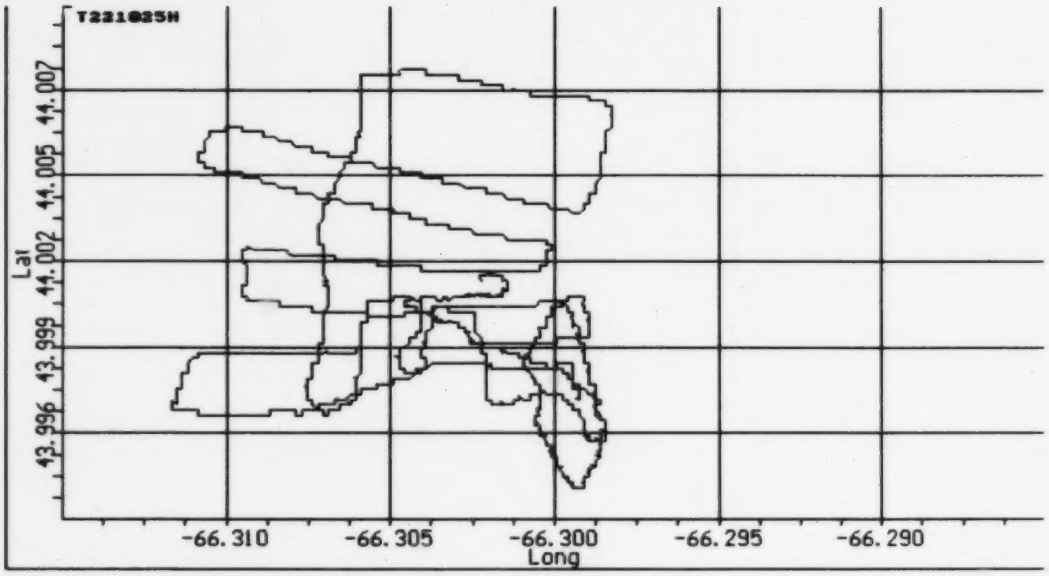


Figure 9. Vessel track of the gillnetter Attiboy on the Trinity Ledge during the evening of September 9, 2001. Segments of the track were extracted to estimate the biomass of herring in the 1.1$km^2$ coverage area.

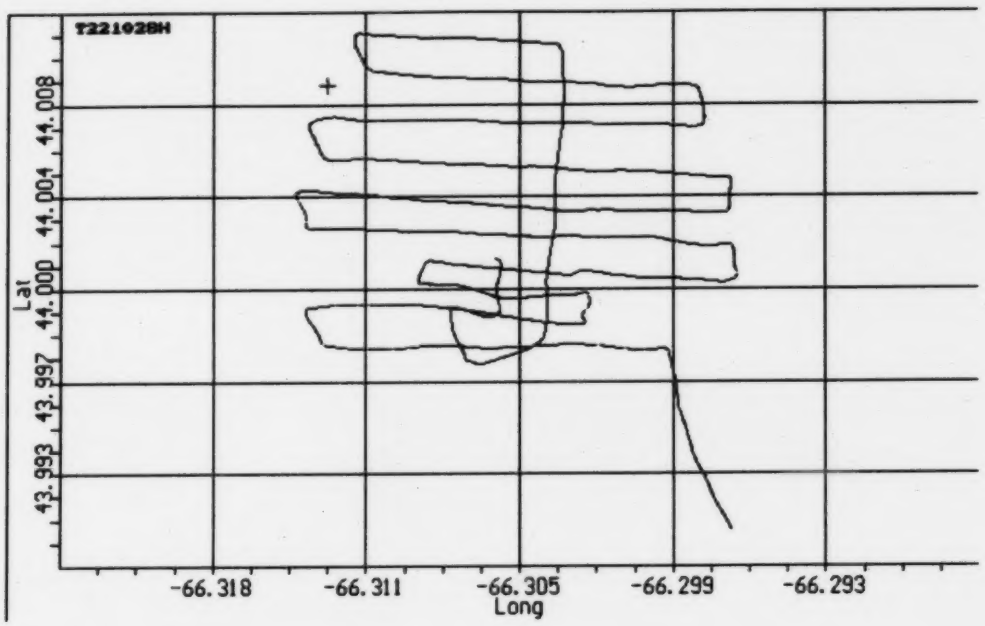


Figure 10. Vessel track of the Attiboy September 11. 2001 on Trinity ledge . Total area of coverage was 1.53 $km^2$.

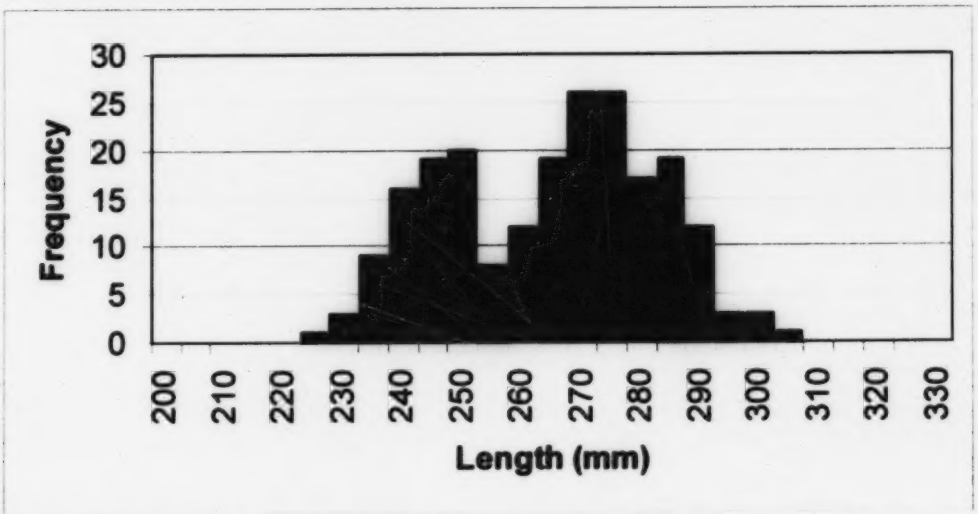


Figure 11. Length frequency distribution of Trinity Ledge herring sampled from a commercial gillnet on August 28, 2001. The mean length of fish was 28.48cm.

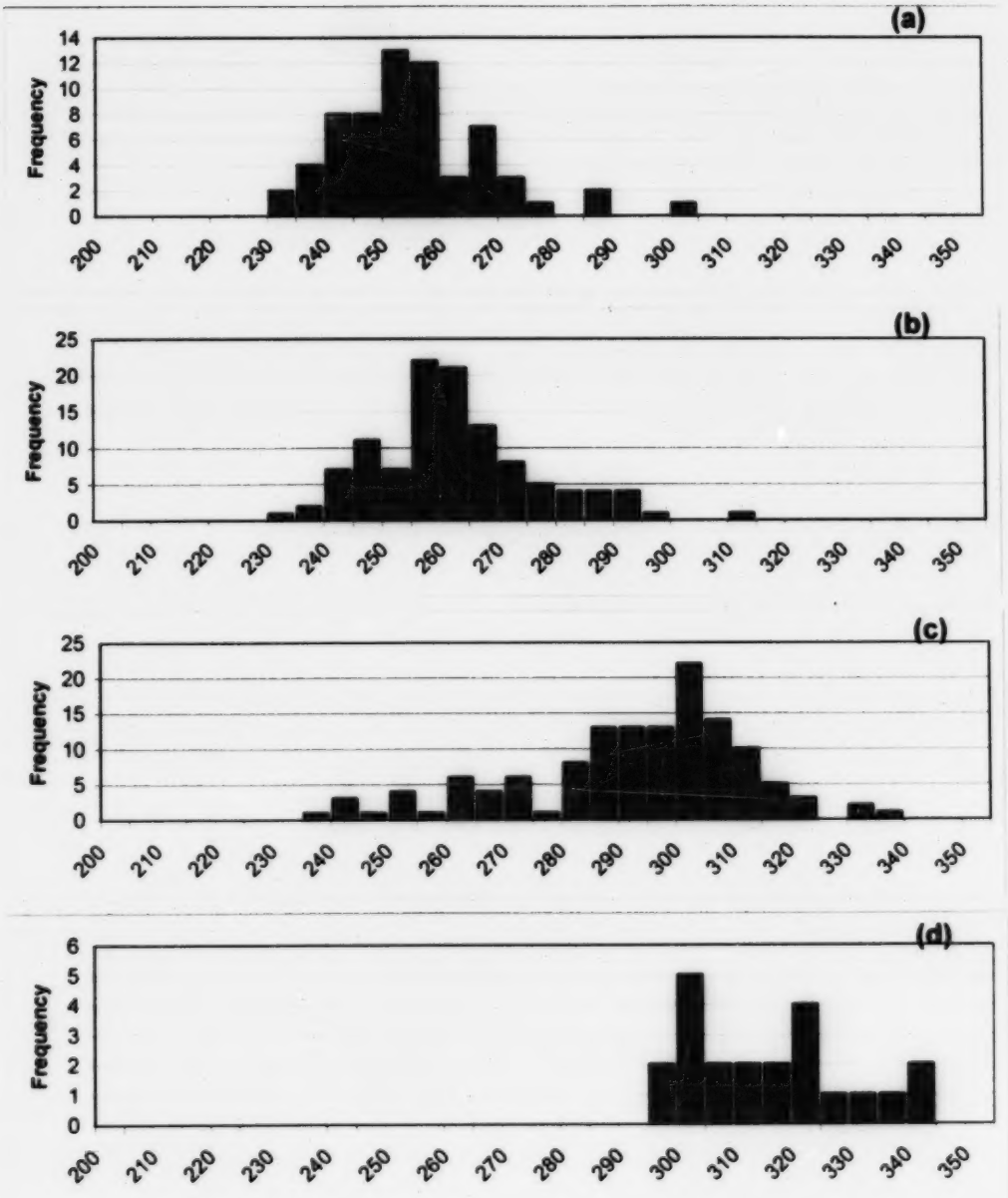


Figure 12. Length frequency distributions of herring sampled on Trinity Ledge, August 24, 2001 using a 4 panel multi-mesh gillnet. The mesh-sizes of the panels were 1 1/2" (a), 2" (b), 2 1/2" (c), 2 7/8 (d).

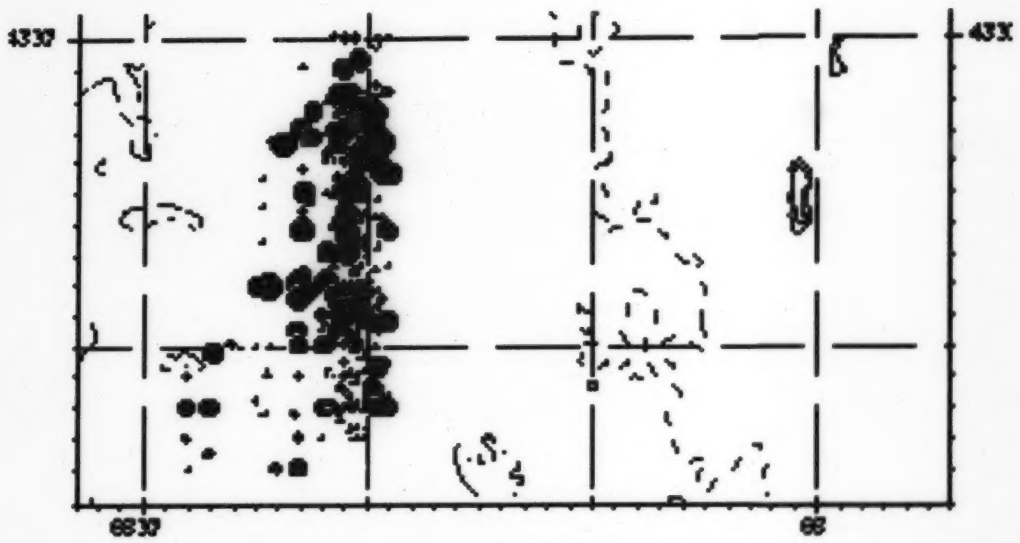

Figure 13. Distribution of herring during the August 27, 2001 survey of the German Bank spawning grounds. Area surveyed equals 200km$^2$.

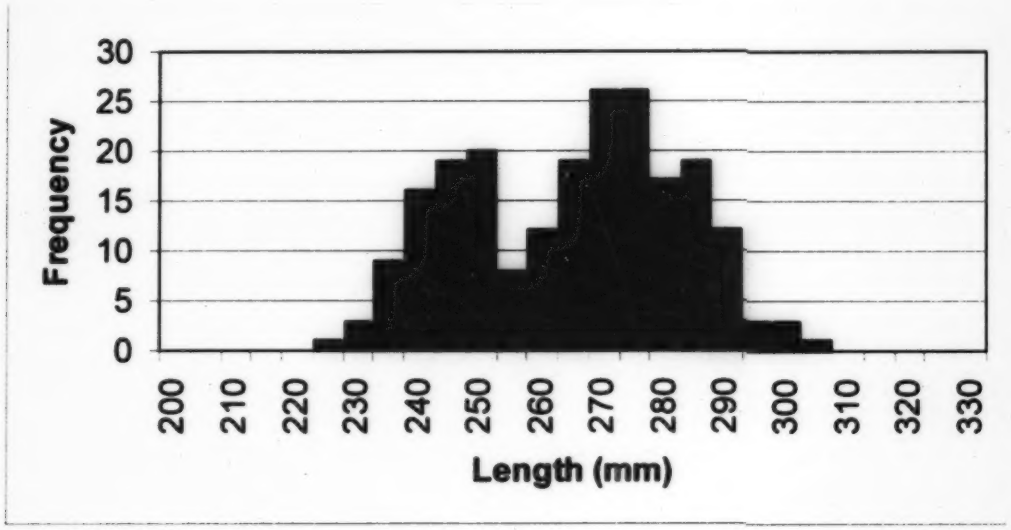


Figure 14. Length frequency distribution of herring sampled from purse seine catches from German Bank on August 27, 2001. The mean length of fish was 28.30cm.

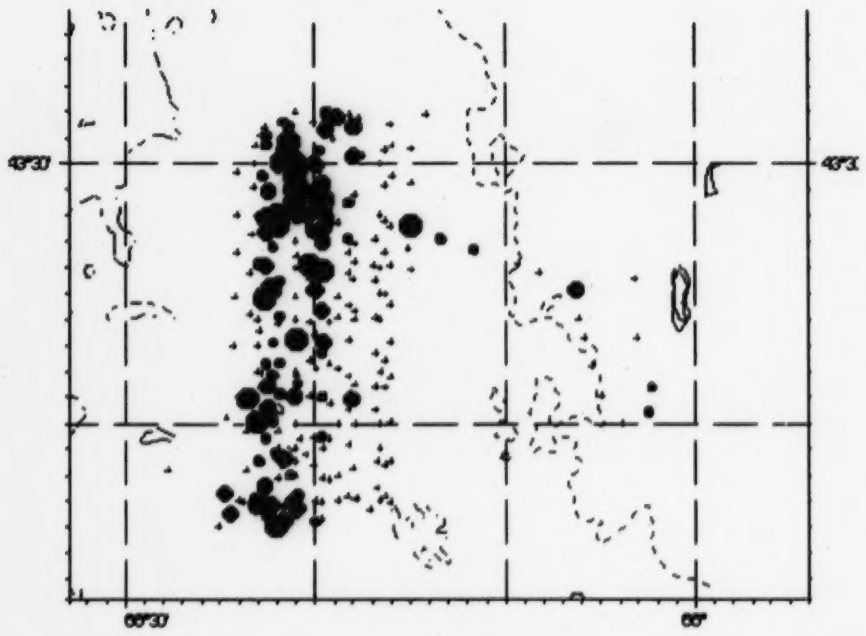

Figure 15. Distribution of herring during the September 9, 2001 survey of the German Bank spawning grounds. Area surveyed equals 325km$^2$.

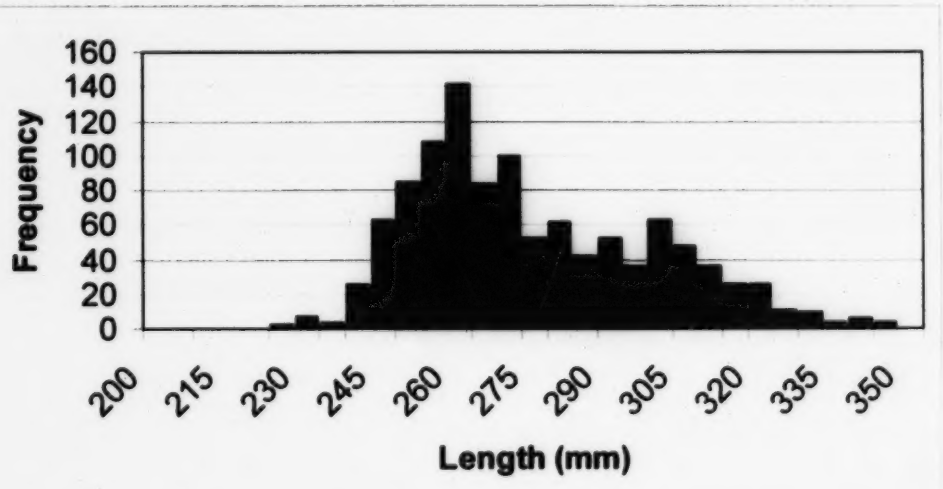


Figure 16. Length frequency distribution of herring sampled from purse seine catches from German Bank on September 9, 2001. The mean length of fish was 27.45cm.

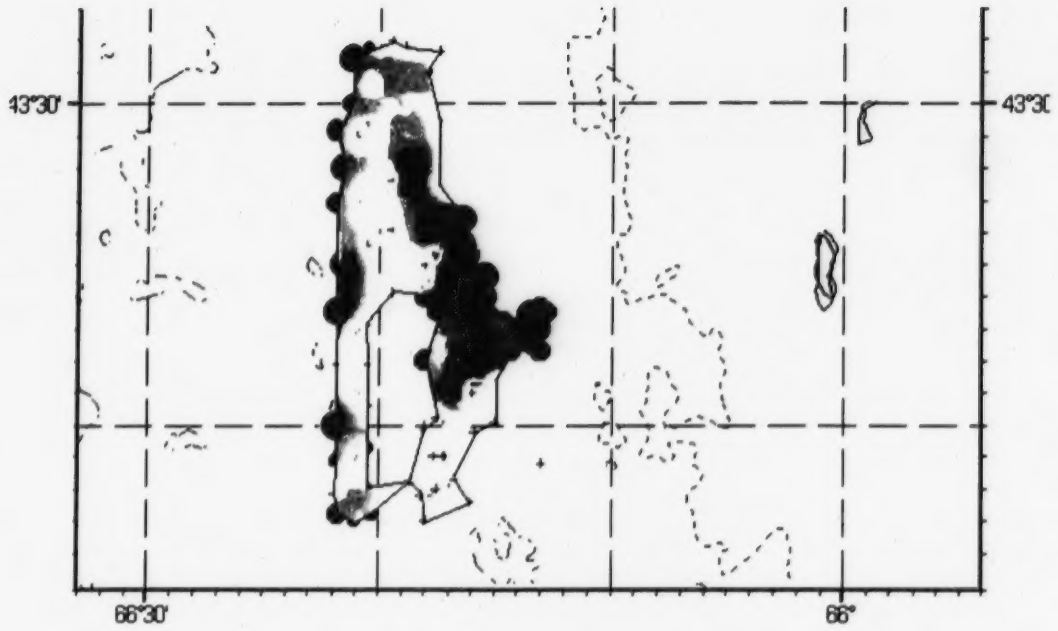


Figure 17. Distribution of herring during the September 13, 2001 survey of the German Bank spawning grounds. Area surveyed equals 200km$^2$.

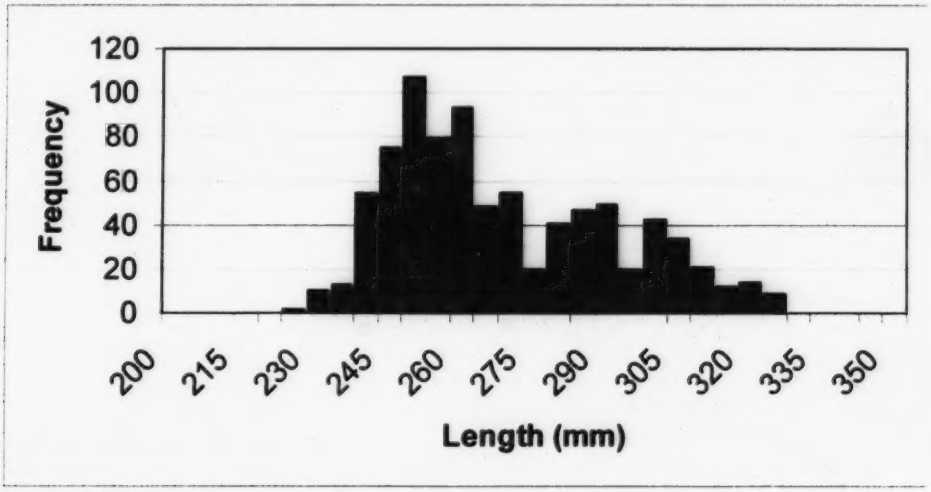


Figure 18. Length frequency distribution of herring sampled from purse seine catches from German Bank on September 13, 2001. The mean length of fish was 26.86cm.

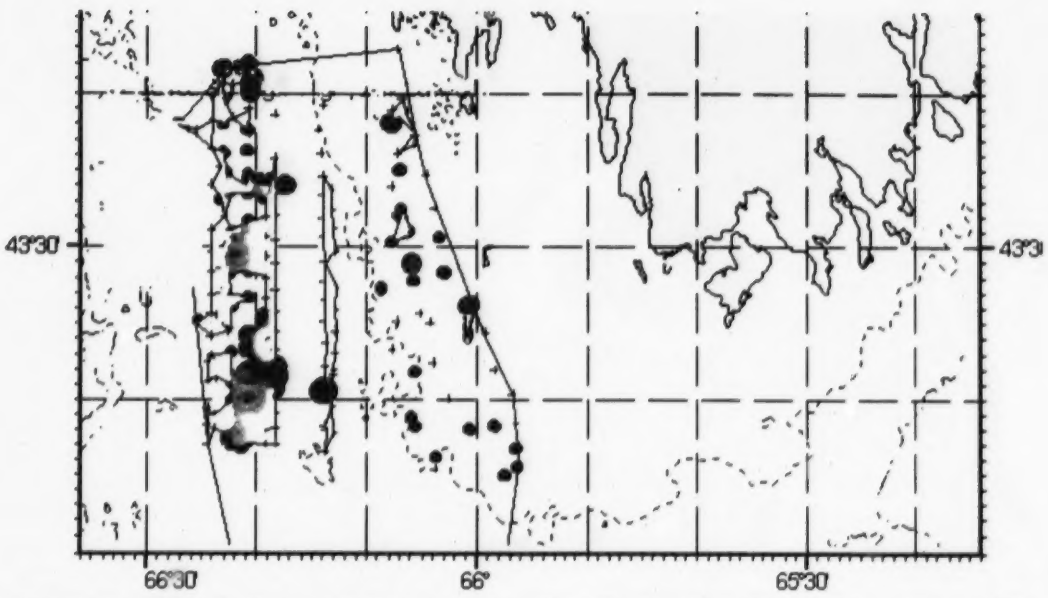


Figure 19. Distribution of herring during the September 25, 2001 survey of the German Bank/Seal Island spawning grounds. Area surveyed equals 425km$^2$.

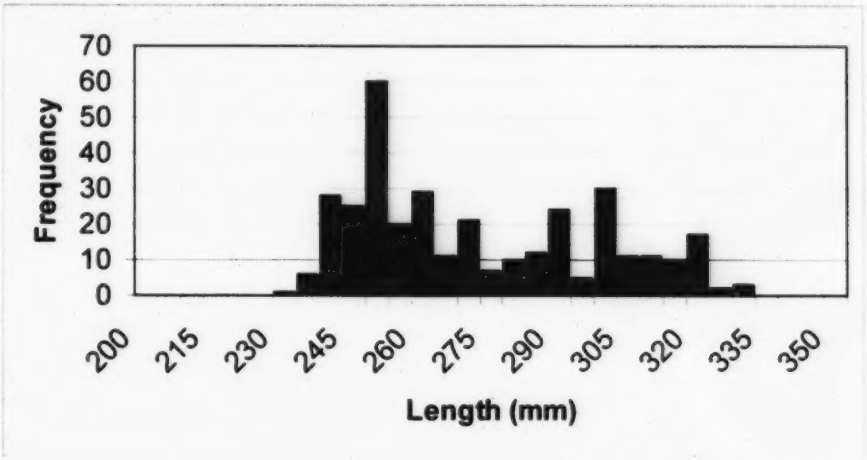


Figure 20. Length frequency distribution of herring sampled from purse seine catches from German Bank on September 25, 2001. The mean length of fish was 27.20cm.

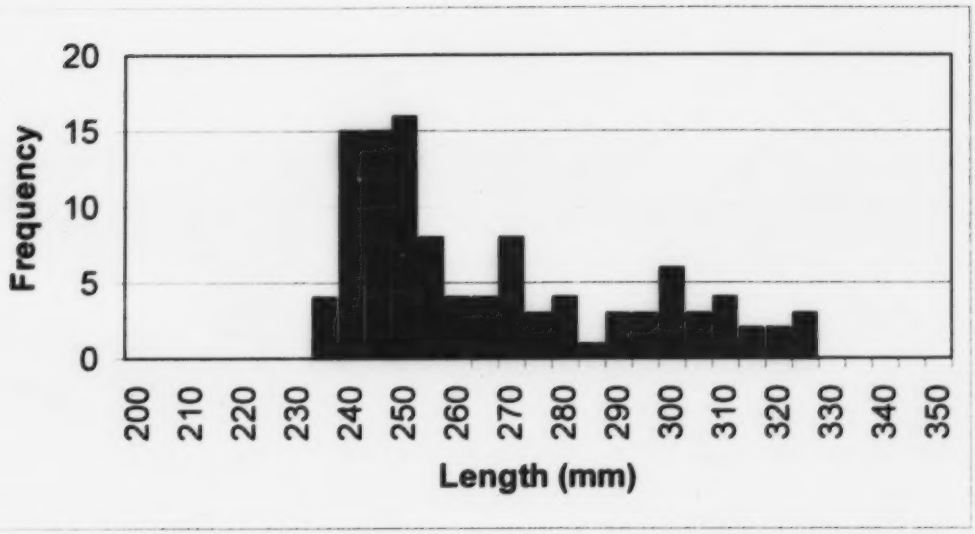


Figure 21. Length frequency distribution of herring sampled from purse seine catches from German Bank on October 3, 2001. The mean length of fish was 26.57cm.

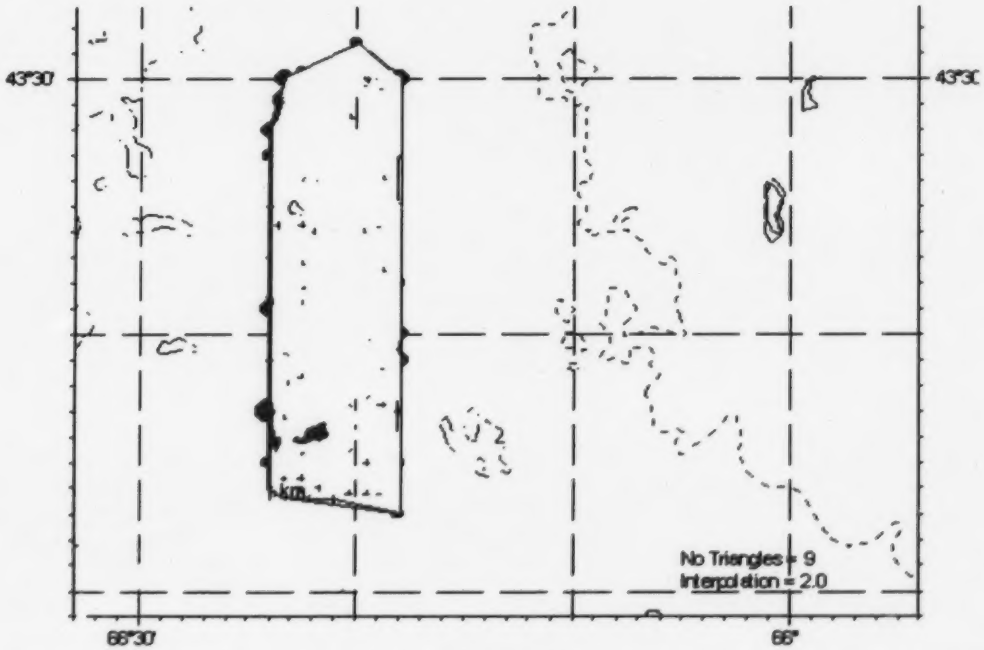


Figure 22. Survey coverage and the distribution of herring during the October 19, 2001 survey of the German Bank spawning grounds.

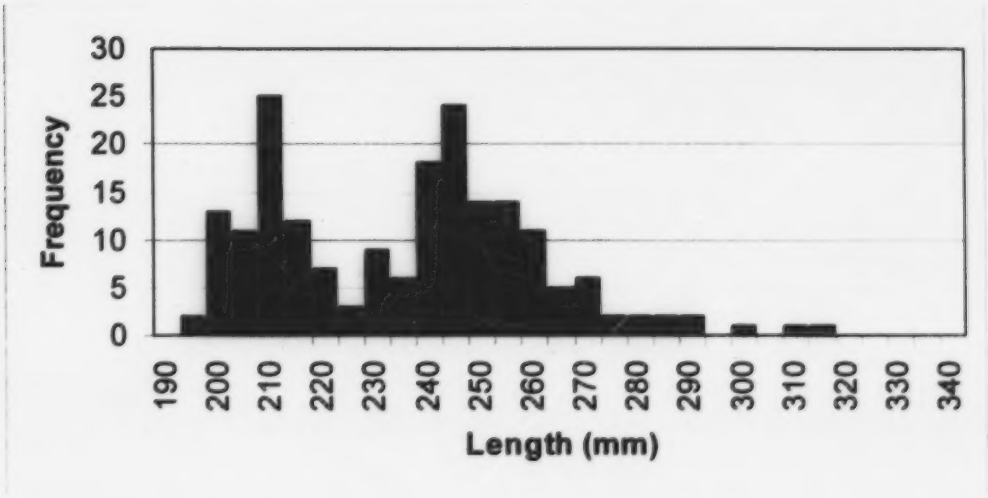


Figure 23. Length frequency distribution of herring sampled from purse seine catches from German Bank on October 19, 2001. The mean length of fish was 23.6 cm.

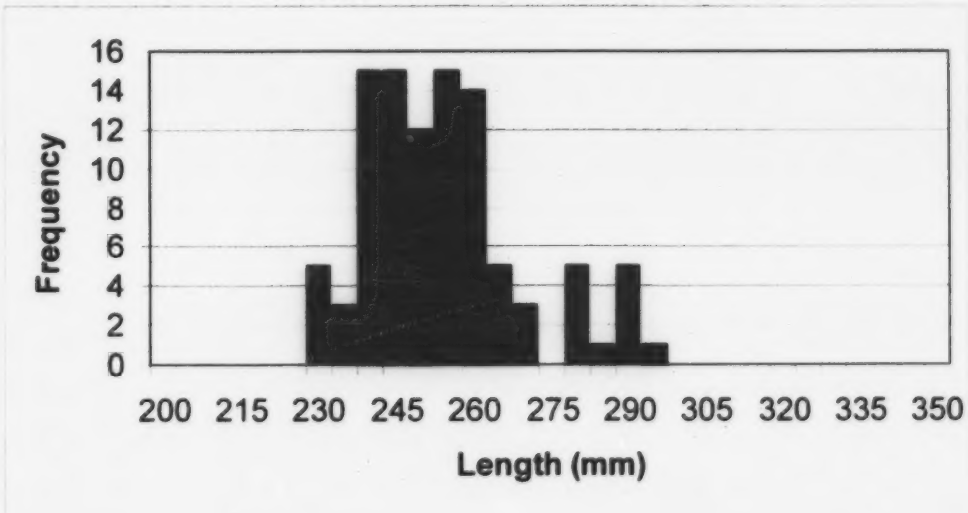


Figure 24. Length frequency distribution of herring sampled from purse seine catches from Browns Bank on October 10, 2001. The mean length of fish was 25.41cm.

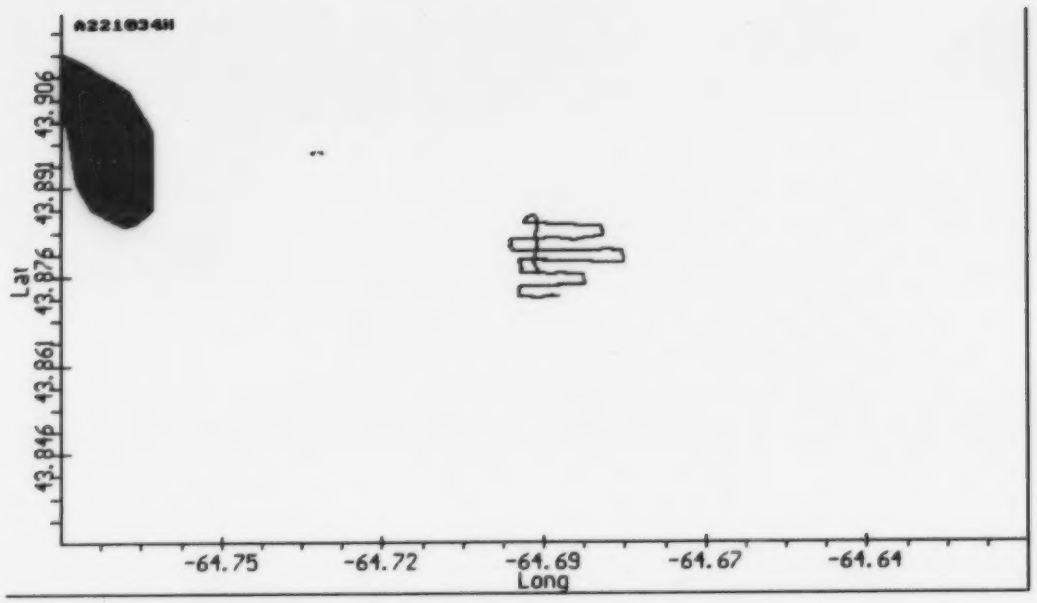


Figure 25. Vessel track of the Attiboy surveying a school of herring near Port Mouton on the night September 19, 2001. The area covered is 2.30 km$^2$.

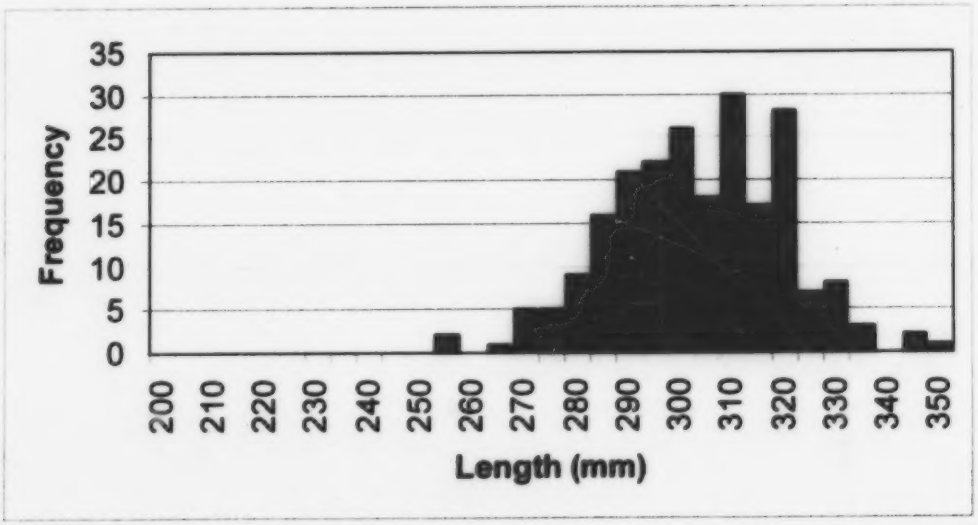


Figure 26. Length frequency distribution of herring collected from a commercial gill net fishery near Port Mouton on September 25, 2001. Mean length = 30.3 cm.

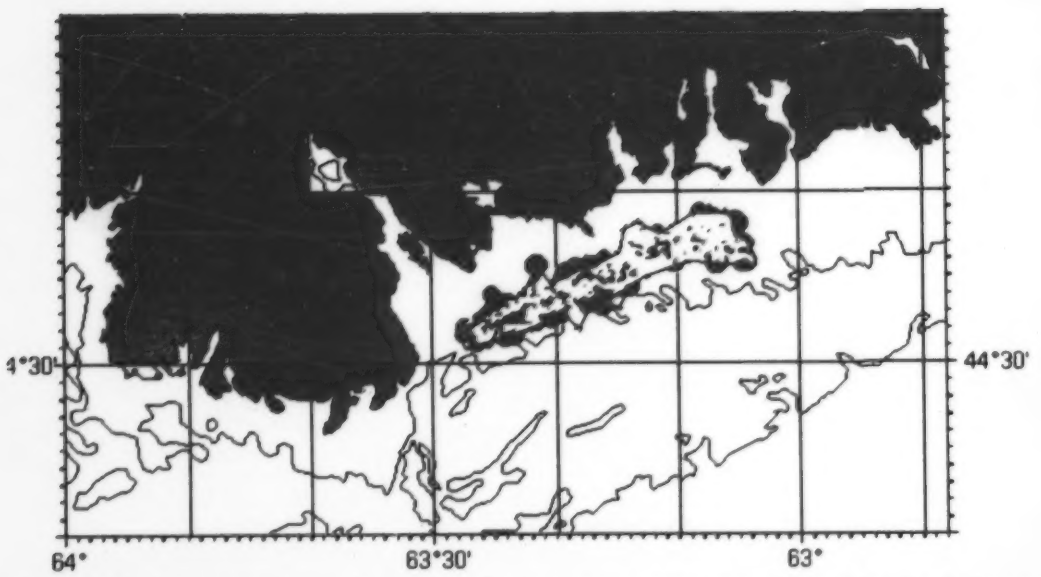


Figure 27. Vessel track of the surveying a school of herring near Eastern Passage on the night of and the distribution of herring during the October 1, 2001. The area covered is 118km$^2$.

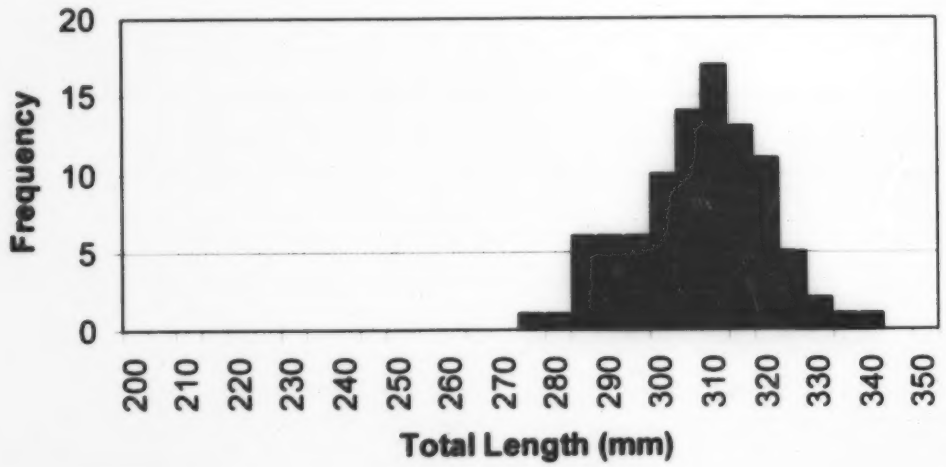


Figure 28. Length frequency distribution of herring collected from a commercial gill net fishery near Eastern Passage on October 1, 2001. Mean length was 30.7cm.

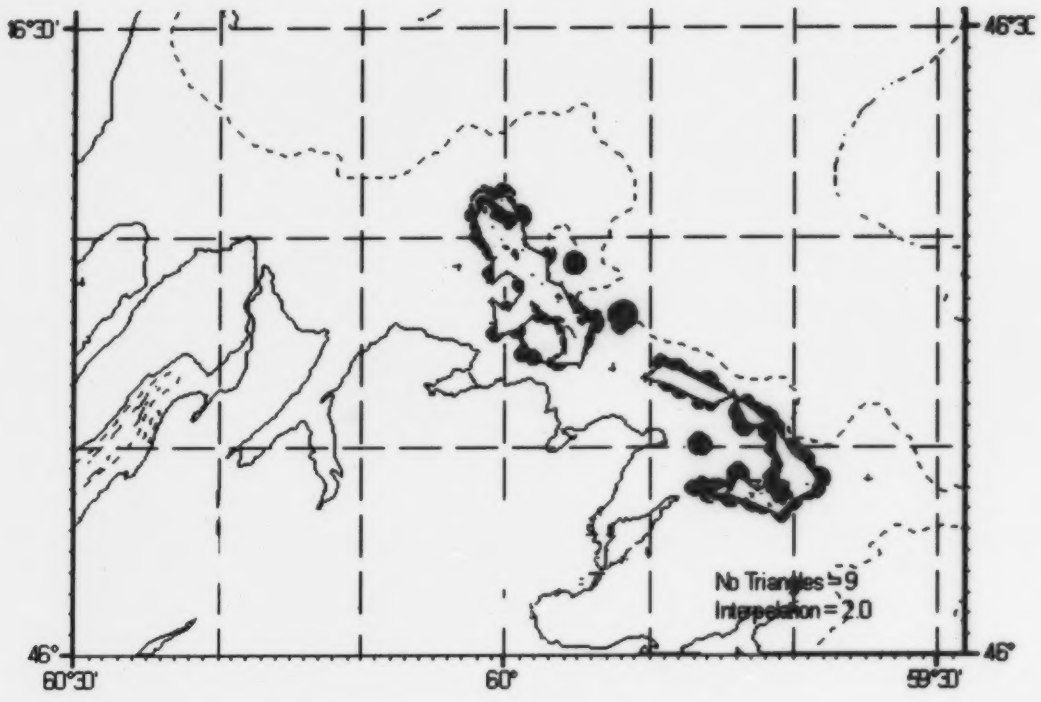


Figure 29. . Vessel track and the distribution of herring for the mapping survey near Glace Bay on the night of September 30, 2001. The combined area covered is 101km$^2$.

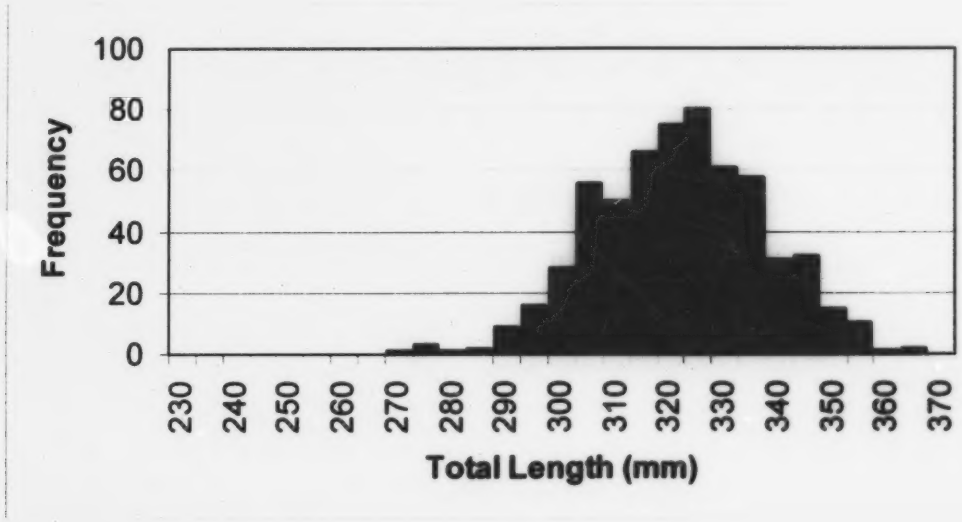


Figure 30. Length frequency distribution of herring collected from a commercial gill net fishery near Glace Bay on September 30, 2001. Mean length was 32.2 cm.

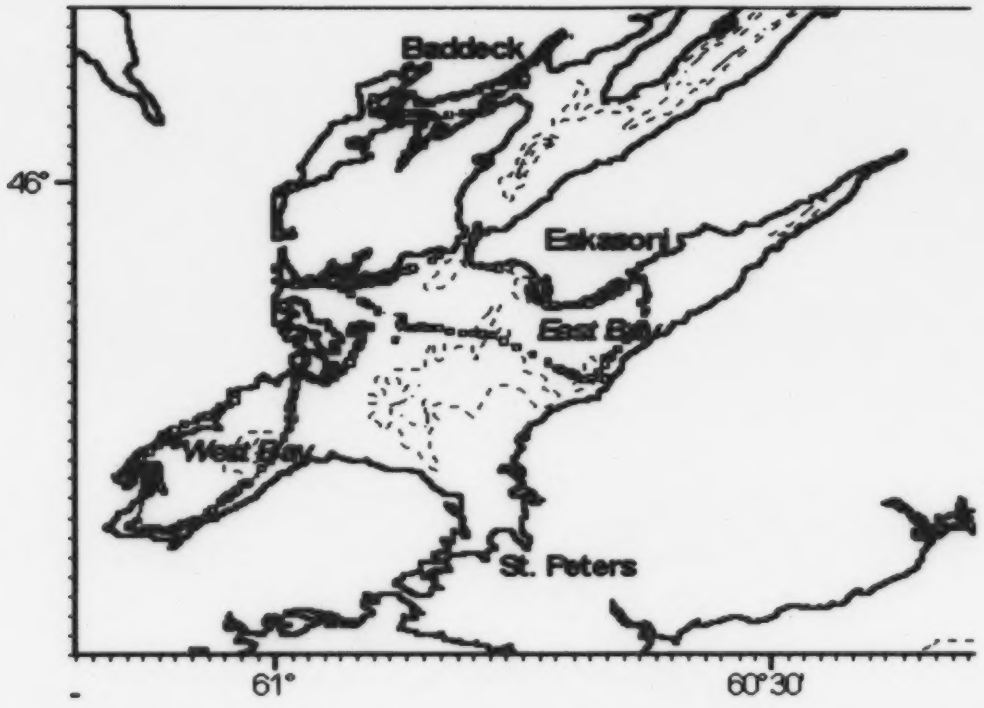


Figure 31. Combined vessel track and fish distribution from mapping surveys conducted in the Bras d'Or Lakes on April 28, 29 and 30, 2001.

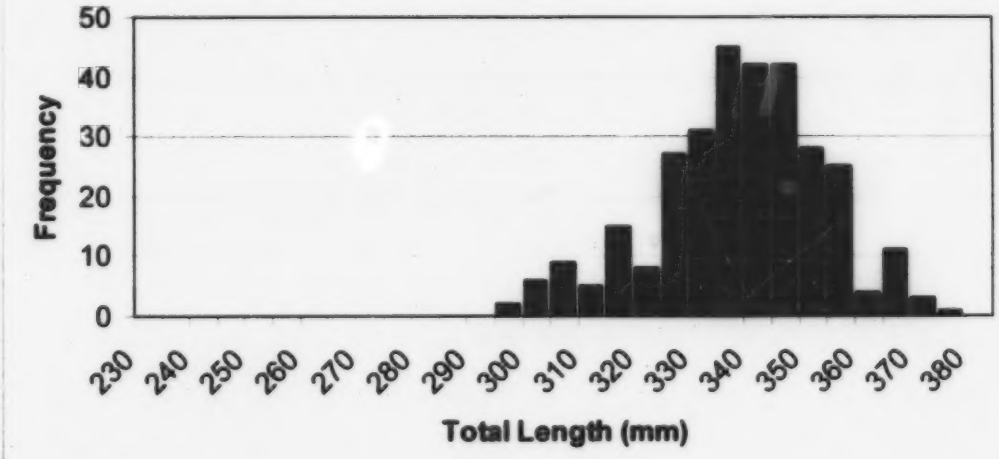


Figure 32. Length frequency distribution of 4 herring samples collected from commercial fishing gear (gillnet) in the Bras d'Or Lakes during the spring of 2001. The mean length is 33.7 cm.

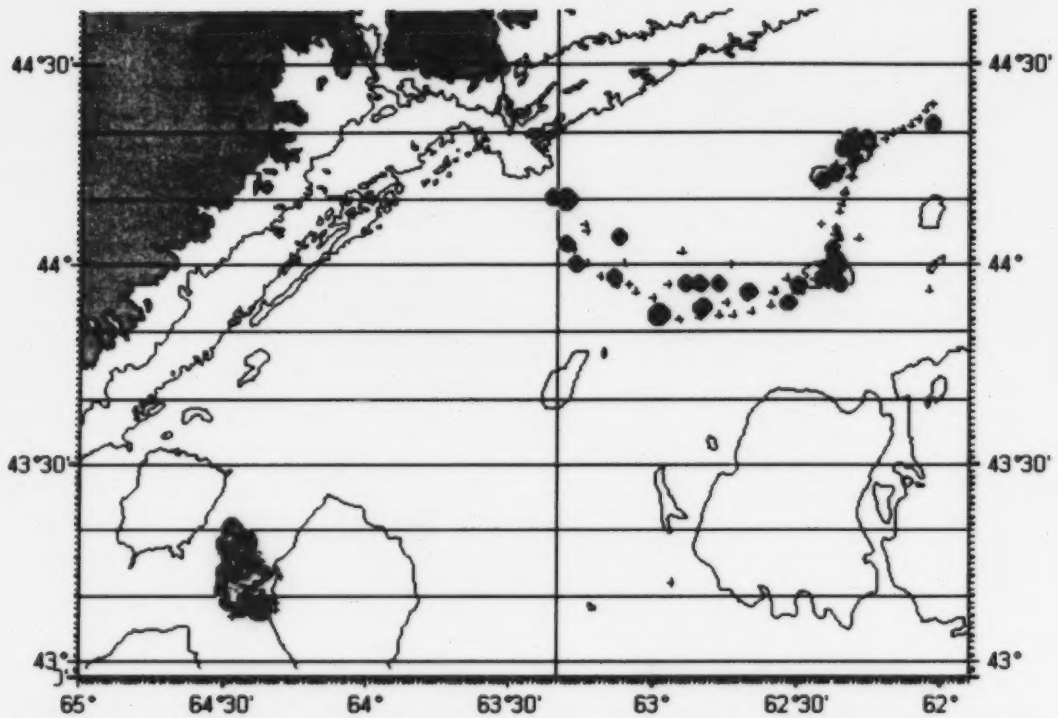


Figure 33 Distribution of herring during the July 4, 2001 offshore banks survey. The two areas of concentration are the Patch and Roseway Bank.

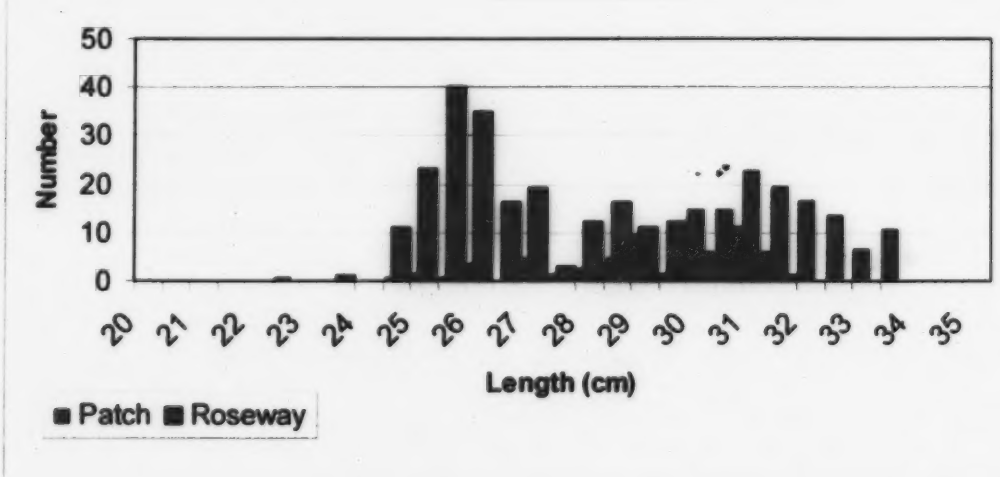


Figure 34. Length frequency distribution of herring sampled from catches of herring on the Patch and near Roseway Bank on July 4, 2001. The data were pooled to obtain a mean length (27.0cm) for estimation of target strength.

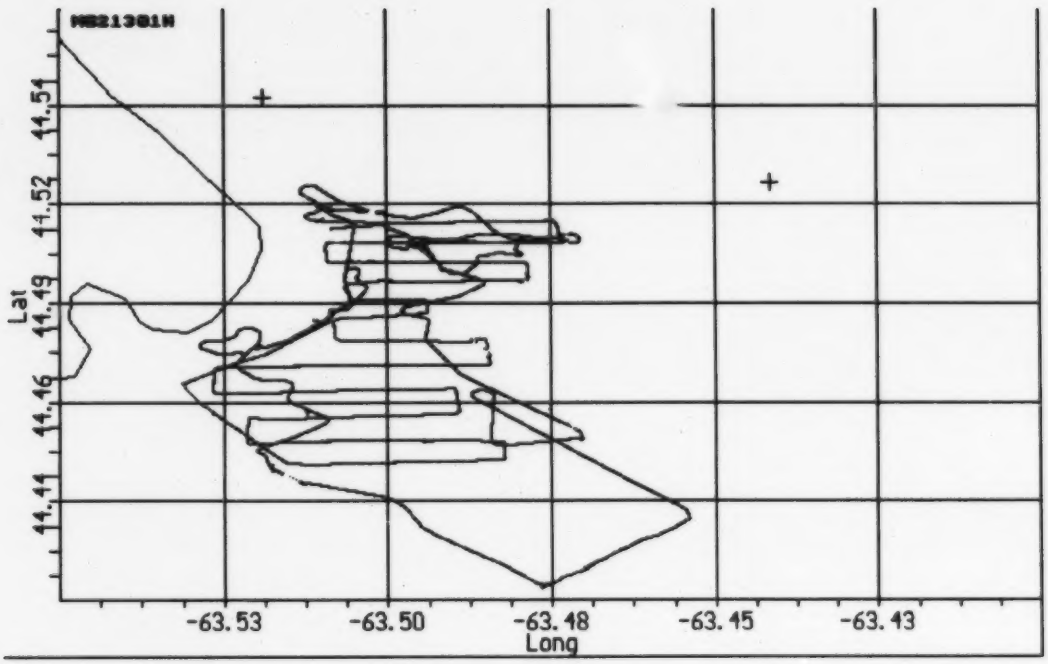


Figure 35. Vessel track of the Margaret Elizabeth off Chebucto Head on the night of January 10, 1002.

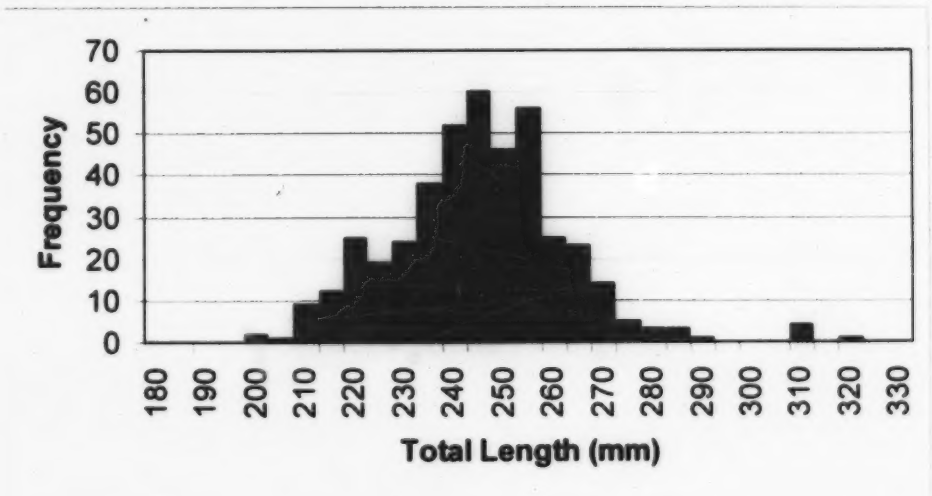


Figure 36. Length frequency distribution of herring from Chebucto Head on January 9, 2002. The mean length was 24.9 cm.

## Appendix A

The following provides a general description of the types of surveys, survey protocol and the analytical procedure used to estimate biomass from the acoustic data collected by scientific and commercial fishing vessels. Prior to 1999, surveys were undertaken on an *ad hoc* basis and usually at the request of the fishing industry. This resulted in some uncertainty as to the turnover time between spawning waves and the potential for double counting of fish. In 1998 a procedure was established to estimate the percent of herring remaining on the spawning ground between surveys when the time between surveys was less than 10 days (Melvin et. al., 1999). To avoid potential problems associated with an elapsed time of less than 10 days between surveys, a survey schedule was established for the main spawning area at approximately two-week intervals for 1999, 2000 and 2001. Additional research was undertaken in 2001 to investigate turnover time on German Bank (Power et al., 2002).

### Surveys

Surveys undertaken by the fishing industry fall into two broad categories – mapping surveys which do not involved quantitative acoustic data, and quantitative surveys which depend heavily on acoustic data to estimate biomass. Most scheduled surveys involve a combination of both types.

### Mapping Surveys

In 2001, surveys that relied solely on the mapping approach, used in the early years of industry based surveying, were few. Most surveys included a combination of both mapping and acoustic data collection. Mapping data (log sheets) were collected on each survey by all vessels participating in the survey to establish the outer bounds and distribution of herring in the survey area. Biomass estimates were also made from the mapping type data to provide a quick approximation of fish numbers and to use as input for the "survey, assess, then fish" protocol when uncertainty prevailed. The procedure involved recording information on fish abundance and distribution observed from the sounders and sonars of vessels without acoustic recording systems. Survey protocol required that parallel transects were run with vessel spacing varying from 1/8 mile to ½ mile, depending on the availability of sonar, to ensure that no large schools were missed. Observations were recorded every 5 to 10 min on standardized data sheets. The observations were later categorized into the 3 density values (light, medium or heavy) and biomass estimated using the area and a relative density category (Melvin *et. al*, 2000a; Stephenson *et. al*, 1998). In most of the 2001 surveys at least one automated acoustic system was available to collect quantitative data.

Mapping data were contoured and plotted using the ACON Data Visualization package and the triangular contour method (Black, 2000). Blanking distance was set to the maximum distance between valid data recordings and varied between 1

and 3 miles depending on the survey. Interpolation between data points was undertaken using the inverse distance weighting gradient approach to compute the density at any given point. Once the area of the three contour levels was estimated, the areas ($km^2$) were multiplied by the appropriate fish density in accordance with the previously defined scale and summed to get the total biomass within the survey coverage area. However, final biomass estimates were based on acoustic density estimates whenever available.

Quantitative Surveys

Industry based structured surveys were used throughout the 2001 spawning season to document the distribution and abundance of herring on individual spawning grounds. Standard operating procedure for surveying involved the presence of DFO scientific staff onboard one or more of the vessels to direct the activities, assign transects, determine coverage (with fishing captains), sample fish and download/collect the data upon completion of the survey. In 2001 most of the data were downloaded by an industry (Herring Science Council) technician. Typically, a series of randomly selected transects were provided to the participating vessels for the area of interest and a two-phase survey design (i.e. search then survey) implemented. The initial phase involved the search for fish on the spawning grounds along the pre-defined transects using vessels equipped with and without acoustic logging systems. Fishing vessels without a recording system would document their observations as if they were undertaking a mapping survey. Once the entire area was covered and the distribution of fish identified, each vessel involved in the survey was assigned a series of transects to execute in the area containing the higher concentration of fish. Biomass estimates were made using the procedure described below for fishing operations, except that transects were usually of similar length and selected at random within the pre-defined area of interest. Transect estimates were weighted for length (i.e. distance traveled) and the mean transect backscatter (converted to $kg/m^2$ using the Foote equation) extrapolated for the survey area to estimate the minimum observed biomass.

Analytical Procedures

The computational procedures for analyzing data collected from standard fishing operations and structured surveys are similar. However, given that the vessel track from standard fishing operations does not follow any standardized survey design, some assumptions have to be made about the area covered and the representative nature of the data. Unfortunately, there are some recording nights when the data are simply too convoluted or too sparse relative to the area covered or the area covered is too small to be incorporated into the SSB for the stock. In recent years fishing captains have attempted to structure their ad hoc recordings by running parallel lines when documenting aggregations of fish as recommended (Melvin and Power, 1999). Furthermore, when the area covered in search of fish is of sufficient size and representative lines (equivalent to transects) can be extracted, an estimate of observed biomass can be obtained.

For structured surveys, transects are usually predefined and represent randomly distributed parallel lines within the survey area. Transects for fishing operations are extracted from the vessel track by dividing the track into a series of non-intersecting segments. Portions of the vessel track where the vessel looped back to take a second look at a group of fish are always removed to prevent over-weighting of areas of heavy fish concentrations.

Fish biomass is estimated by selecting segments of the vessel's track (transects), computing the distance weighted average area backscatter (Sa), estimating the mean weight of fish/$m^2$ under the vessel using the Foote target strength equation (Foote, 1987) and multiplying by the area covered. Target strength estimates are based on herring length frequency samples and associated weights collected from several commercial vessels fishing in the area of interest as follows:

$$TS \text{ (target strength)} = (20 \log(\text{length}) - 71.9) - 10 \log(\text{weight}) \quad \text{in dB kg}^{-1}.$$

Length frequency data are normally obtained from the survey vessel or vessels fishing in the survey area for TS calculation and target verification. The weight component of the TS equation is computed from recent data on the weight/length relationship for the mean size of fish observed. In the event length frequency data are unavailable, a standard TS of –35.5 is used for calculating biomass. Such events occur when gillnet samples are collected (selective for larger size) or no fishing is undertaken. The standard target strength corresponds to the TS of a 28.0cm herring in September. This represents the lower end of the observed mean spawning lengths and generally translates into smaller biomass estimate.

The area backscattering coefficient (Sa) is initially computed by averaging the return signal for a specific navigational interval (usually 20 navigational fixes) along the transect and weighted by the distance traveled during that interval. The average Sa values, weighted for distance, are then used to compute the mean Sa (dB $m^{-2}$) for the transect. Average biomass density per transect (sample unit) was computed from the estimated Sa and TS as follows:

$$\text{Biomass density/transect} = 10^{(\text{mean Sa - Target strength})/10} \quad \text{in kg m}^{-2}$$

The area covered by the vessel is determined by fitting a rectangle or polygon over the vessel tracks and estimating the area. When available, sonar data are used to determine the boundaries of the fish schools. The area is then multiplied by the biomass density/stratum to determine the biomass in the area covered by the fishing vessel. Standard Error (S.E.) is estimated from the standard deviation of the transect biomass density, where n is the number of transects. The area of coverage is then multiplied by standard error to determine the SE of the overall biomass estimate.

Table A1. Summary of weightings for each category used in mapping surveys. The tonnes/set is based on the fishermen's estimate of their catch if they set on

the school of fish, converted to $km^2$. The acoustic values are the range of tonnages estimated from acoustic recordings and categorized by the observers.

| Category | Tonnes/Set | Tonnes/$km^2$ | Acoustic (tonnes/$km^2$) |
|---|---|---|---|
| **No Fish** | 0 | 0 | 0 |
| **Light** | 5 | 200 | 230 - 250 |
| | 10 | 400 | |
| **Moderate** | 25 | 1000 | 600 - 1300 |
| | 50 | 2,000 | |
| **Heavy** | 100 | 4,000 | 2,000 – 11,000 |
| | 200 | 8,000 | |
| | 250 | 10,000 | |
| | 500 | 21,000 | |